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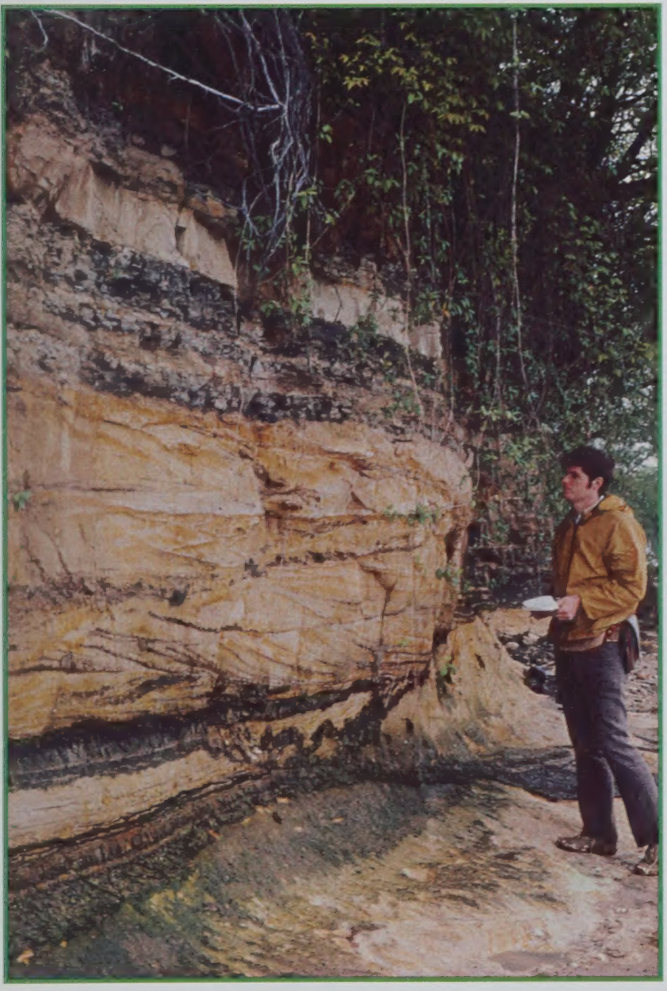
Geology and Paleontology of the James River: Richmond to Hampton Roads

Lauck W. Ward



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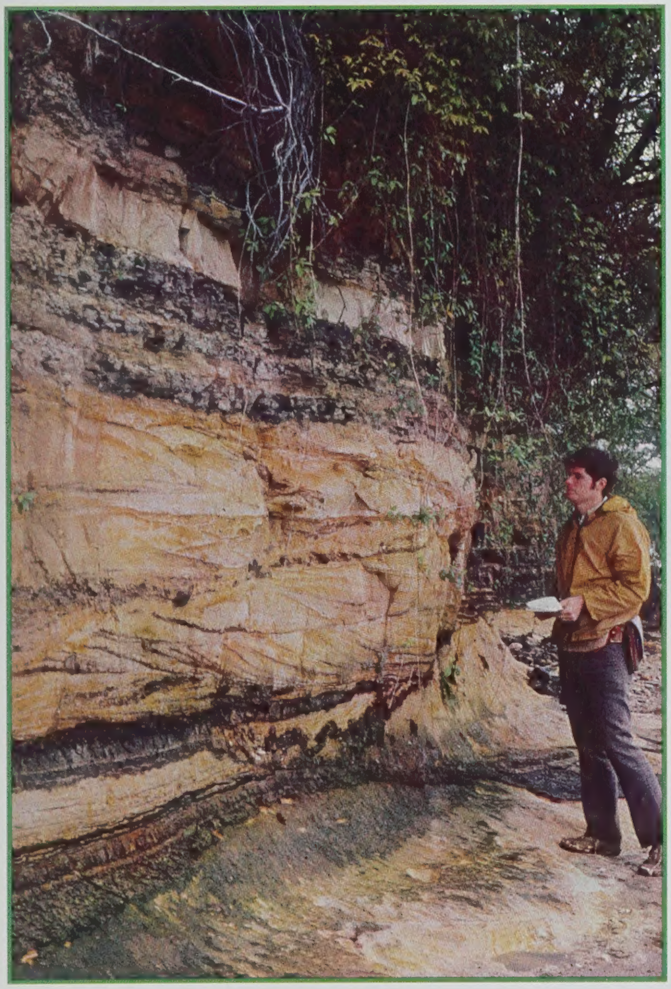

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Cover Illustrations:

Left: Dutch Gap, right bank of the James River, Chesterfield County. Premier East Coast locality for Lower Cretaceous plants. Studied continuously from the late 1800's until the middle 1990's when it was covered with riprap. Shown are cross-bedded deltaic sands and silts. Blake Blackwelder for scale. Photo by L.W. Ward, April 29, 1975.

Right: Mount Pleasant, Surry County, upriver end of property, Type Section of the Eastover Formation, exposed (from bottom to top) are the Claremont Manor Member, Cobham Bay Member, Sunken Meadow Member, and Rushmere Member. Gordon Lawrence for scale. Photo by L.W. Ward, April 25, 1978.

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Geology and Paleontology of the James River:
Richmond to Hampton Roads

Lauck W. Ward

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Preface

In my first visit to the James River on the Virginia Coastal Plain in 1952, I went to visit relatives at Scotland Wharf in Surry County, directly across from Jamestown. I was drawn to the beach, and there I found several preserved shells. Even in my youth I recognized these specimens to be scallops and that their natural habitat was marine, not fresh water. I asked several of the local inhabitants where they could have come from and I was told they were brought there by the Indians. Thousands of these scallops were sticking out of the banks and the people living there thought the shells were coming from middens. It was nine years later that a knowledgeable amateur (George Schraudt of Richmond) took me to Surry County and explained the ancient marine origin of the shells. Later I identified my first Coastal Plain finds as *Chesapecten middlesexensis,* a late Miocene extinct scallop.

It was only recently that I realized that at least one of the first English explorers of the James River 345 years earlier, in 1607, not only recognized the origin of the fossil deposits, but correctly deduced how they got there. And this he did long before the first geologists and paleontologists arrived at the same conclusion. E. W. Haile (1998) reproduced the descriptions of Virginia as written by the original explorers. One of those was William Strachey who wrote *The History of Travel in Virginia Britannia: The First Book of the First Decade.* This description was written between 1607 and 1612, but it wasn't published for 237 years. However, it stands as the original description and interpretation of Virginia's geology of the Coastal Plain. Strachey wrote the following:

> "All the low land of South and North Virginia is conjectured to have been gained naturally out of the sea, for the sea, through his impetuous and vast revolution (who knows not?) swaying upon every coast, in some places wins and in other places loseth. And we find within the shores of our rivers whole banks of oysters and scallops which lie unopened and thick together as if there had been their natural bed before the sea left them."

Strachey correctly deduced that the sea rises and falls, and that some areas are elevated and exposed while others are covered by the sea. In addition he noted the way the fossil mollusks were exposed in the cliffs and recognized them to be in natural or living positions, not just washed into that area.

This guidebook to the geology of the lower James River is, therefore, dedicated to William Strachey, who was the first to describe and interpret the geology of the area and to George Schraudt, who introduced me to coastal plain geology on the James River on March 4, 1961.

Geology and Paleontology of the James River: Richmond to Hampton Roads

Lauck W. Ward

GEOLOGIC SETTING

Stratigraphic units exposed in the Chesapeake Bay area consist of Mesozoic and Cenozoic coastal plain beds that were deposited in an area known as the Salisbury Embayment (Figure 1). This embayment covers parts of New Jersey, Delaware, Maryland, and Virginia. This depocenter was the site of intermittent marine overlap and deposition during the Early and Late Cretaceous and most of the Tertiary. Beds there range from fluvial to deltaic to lagoonal to open-shelf and were deposited in a wedge-like configuration with the thin, shoreward edge overlapping the Piedmont. Eastwardly the beds thicken, in some cases, to several thousand feet.

The lithology, thickness, and dip of the various beds deposited in the Salisbury Embayment are, to a great extent, structurally controlled. This control consists of several orders of magnitude. Of the first magnitude is regional tilting of the entire Atlantic coastline, much as it is today, with the entire northeastern coastal plain submerged. Of a lesser magnitude is the independent structural movement of the various basins or depocenters, and the intervening arches, or high areas. These high and low areas moved independently of each other creating a stratigraphic mosaic that was unique from basin to basin. Of a third order of magnitude was a basin shift that took place in the Miocene and Pliocene. During the Cretaceous and early Tertiary, the Salisbury Embayment was aligned northeast-southeast with the seaward-dipping direction to the northeast. This alignment continued into the middle Miocene, but the basin shifted to the south. In the late Miocene, the basin began shifting dramatically to the south and the alignment of the basin became increasingly to the southeast. This southeast dip of coastal plain beds is existent today. The basin shifted incrementally southeastward until, in the late Pliocene, the locus of the embayment had moved into the Albemarle Embayment in northeast North Carolina. A fourth order of structural movement in the Salisbury Embayment is that of the localized down-dropped graben structures that occur along northeast-southwest trending lineaments. These grabens are related to early Mesozoic rifting and cause certain areas to become unstable. These areas became reactivated at certain times during the Cretaceous and Tertiary, possibly due to sediment loading, resulting in structural highs behind which finer sediments accumulated. Thus, each of these structural elements contributed to the overall depositional patterns on the coastal plain and in the Salisbury Embayment.

Depositional environments in the Lower Cretaceous were principally alluvial and upper deltaic, consisting of pebbly, coarse to fine, partially arkosic sands. These sands contain relatively thin lenses of clay and lignitic clays which contain leaf impressions. The Upper Cretaceous beds consist mainly of deltaic and shelfal marine sands which, in some beds, are quite fossiliferous. Lower Tertiary deposits consist of glauconitic silty sands containing varying amounts of marine shells. The Tertiary beds are primarily marine-shelf deposits and the alluvial and deltaic, nearshore facies are generally lacking. The same is true for the upper Tertiary beds which consist of diatomaceous silts, silty sands, and shelly sands. The Salisbury Embayment had a warm-temperate to subtropical marine setting through much of its history. During the late Tertiary the temperate molluscan fauna became somewhat endemic so that abruptly cooler conditions in the late Pliocene caused a major local extinction involving taxa that had been successful since the Oligocene.

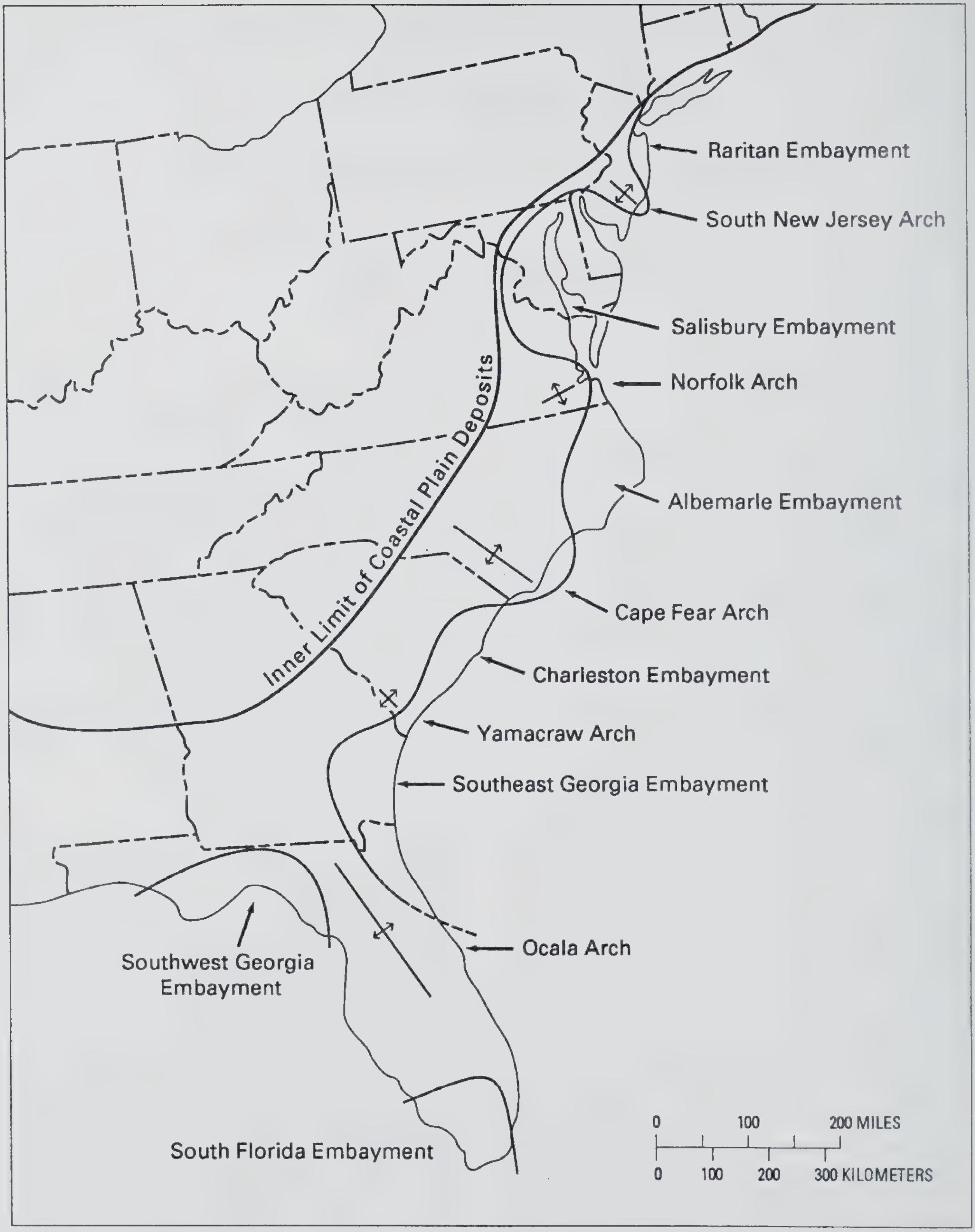


FIGURE 1. Principal Structural features of the Atlantic Coastal Plain.

STRATIGRAPHY

Potomac Group

Early work on the Lower Cretaceous in Virginia and the James River was done by important workers such as Darton (1891, 1911), McGee (1888, 1890, 1891), Ward (1895), and Fontaine (1889, 1896). The following is extracted from E. W. Berry (1912). It is still an accurate description of the Lower Cretaceous deposits along the James below Richmond and has been field-checked by the author. The present author's notes are in [brackets].

> Along the eastern border of the Piedmont Plateau, lying for the most part directly on the flanks of its ancient crystallines and constituting the basal element of the Atlantic Coastal Plain, is a series of mostly unconsolidated, arenaceous, arkosic, argillaceous and often ferruginous or lignitic sediments of highly varied character. Their outcrop constitutes a relatively narrow belt, extending from Pennsylvania to Alabama, and ranges from a few to 20 miles in width, its landward boundary lying somewhat westward on the "fall-line." The thickness of the beds at the point where they pass beneath tide, ranges from 100 to 1,000 feet, dependent largely upon whether the full sequence of formations is present or not, although the formations themselves are very variable in thickness.
>
> The flora of these deposits is a highly varied one consisting of equiseta, numerous ferns, cycads and conifers, a few monocotyledons, and a considerable variety of dicotyledons especially in the upper beds. The known fauna is a meagre one including a few pelecypods and gastropods of brackish water or estuarine habitat, a single fish and a considerable number of reptiles, especially dinosaurs. From the Arundel formation in the Maryland area both gigantic and diminutive forms of this order have been collected as well as the remains of stegosaurs and crocodilians.
>
> That the Potomac sediments were laid down as terrestrial, lacustrine and fluviatile sediments, combined with contemporaneous deposits in shallow water along the Lower Cretaceous shoreline, is indicated by the absence of any strictly marine fossils and sediments, and by the presence of a few estuarine species of shells, and by the abundance of delicate plant remains often but slightly if at all triturated. The fossil wood is also frequently silicified or lignitized without having suffered much from decay. The coarseness of a large proportion of the materials, the frequency of marked current bedding, and the presence of a large amount of coarse gravel or even cobbles, effectually confirms the littoral and estuarine conditions under which the Potomac formations were deposited.
>
> The deposits constituting the Potomac group were at first thought to constitute a single formation and in 1886 Dr. W. J. McGee applied the name Potomac to them because of their extensive development in the Potomac River basin near Washington. Later investigations in Maryland have clearly demonstrated the fact that these deposits do not constitute a single formational unit, and in 1897 Clark and Bibbins proposed a four-fold classification which has now come to be generally accepted. The formational names in order from the oldest to the youngest were the Patuxent, the Arundel, the Patapsco, and the Raritan. More recently the uppermost of these formations, the Raritan, has been referred to the Upper Cretaceous.
>
> The Patuxent is the most constant from Maryland southward. The Arundel attains a considerable development in central Maryland, but disappears to the northward in northeastern Maryland and to the southward in southern Maryland. The Patapsco is largely developed from Delaware to the vicinity of Fredericksburg, Virginia, where it disappears. The known Raritan extends from the islands off the southern coast of New England to southern Maryland where it is transgressed by much later deposits of Tertiary age.
>
> The total exposed thickness of the Potomac formations in Virginia in the region of their outcrop is about 500 feet. The formations thicken down the dip to the eastward, and in all probability the Raritan also, although undifferentiated, is present beneath the Tertiary cover. At Fortress Monroe the combined thickness of the Potomac formations, penetrated in the new government well, is about 1,300 feet.

The Patuxent Formation

Name.—The Patuxent formation, so called from the Patuxent River, Maryland, where the deposits are well exposed, constitutes the basal portion of the Potomac group [named by W. B. Clark in 1897].

Stratigraphic relations.—The Patuxent beds rest throughout most of their area, with marked unconformity, upon the crystallines of the Piedmont and the contact is observable at numerous outcrops. In a limited area around Doswell the Patuxent rests upon the Triassic. In most of the region from Alexandria to Fredericksburg the Patapsco unconformably overlies it. South of Fredericksburg either the Eocene or the Miocene deposits directly overlie the Patuxent. The Lafayette and Pleistocene deposits also frequently cover the Patuxent outcrops along the larger valleys.

Lithologic character.—The materials composing the Patuxent are variable, the formation frequently changing its lithologic characters rapidly in both vertical and horizontal directions. The deposits consist chiefly of light-colored sands, sometimes almost entirely made up of pure quartz grains, but usually containing a large amount of kaolinized feldspar (arkose) resulting from the decomposition of granitic rocks in the region to the westward. Mica flakes derived from the same source are very abundant at certain localities as are also greenish clays which derive their color from the chloritic schists of the Piedmont. Above Dutch Gap along the James River certain beds composed of quartz, mica, and kaolin so closely resemble the residual materials resulting from the decay of the granitic rocks that the planes of stratification are almost the only clue to their real origin. The quartz grains are generally quite well rounded, although in some places, as in the locality above cited, they are decidedly angular. The sands locally become indurated, sometimes so firmly as to be of value as a building stone. Before the day of railroads these indurated layers were quarried in a number of places. At Aquia Creek the United States government in the early part of the last century [early 1800s] quarried a sandstone from this formation for the construction of the White House, the old portion of the Capitol, and other public buildings in Washington. The old lighthouse at Cape Henry is built on this Aquia freestone, as are also the local foundations, etc. On the north shore of the Rappahannock River just opposite Fredericksburg there is also a thick bed of Patuxent sandstone but the most extensive deposit of these indurated sands occurs at Point of Rocks on the Appomattox River below Petersburg. Here there is an indurated arkosic conglomerate, extending from the water's edge to the top of a nearly vertical bluff 80 feet in height. Some layers are very firmly cemented and the material from them has been quarried from colonial days for local use in the construction of walls and buildings.

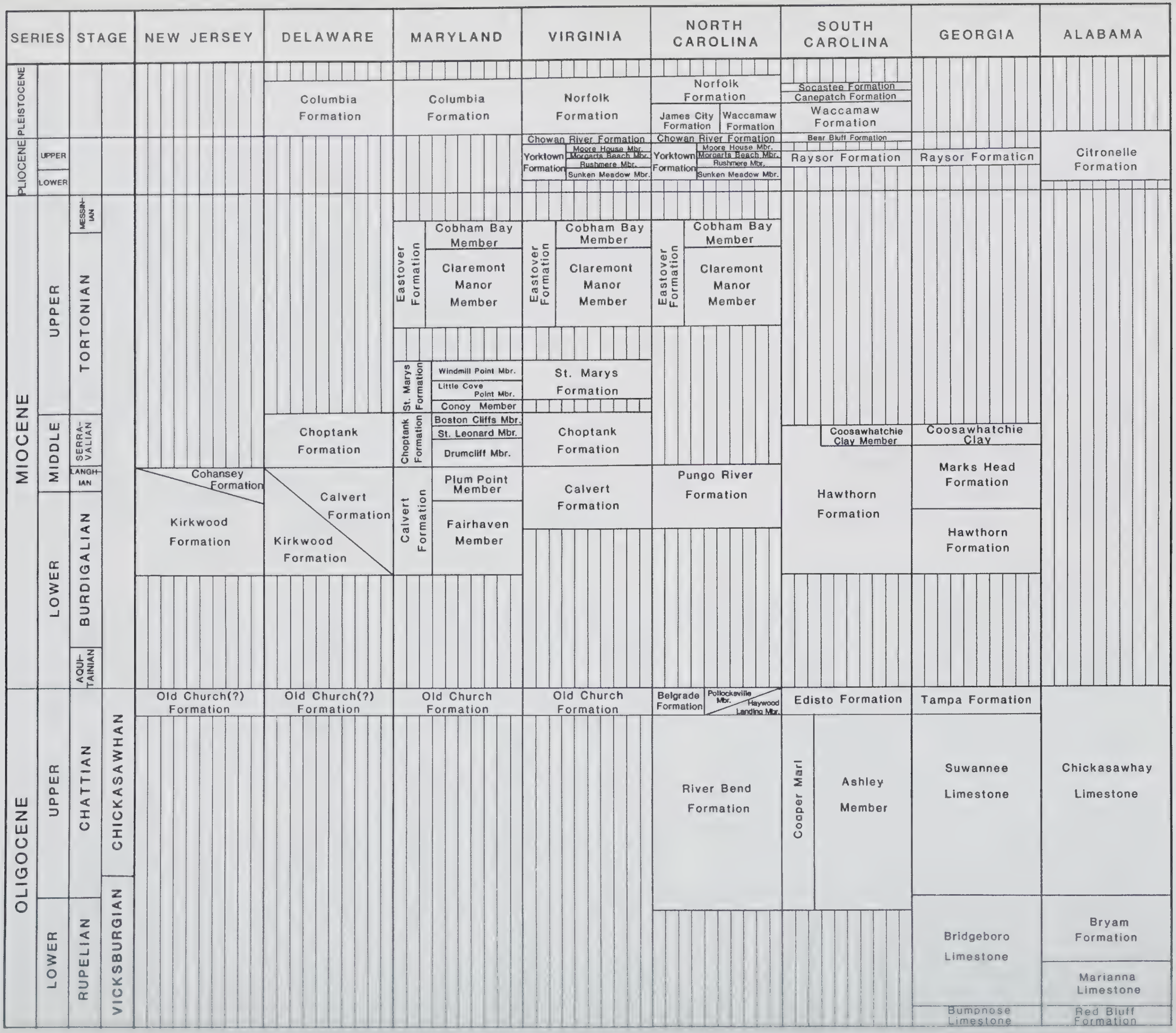
Cobbles and boulders are not uncommon in the Patuxent deposits. Sometimes they form distinct beds while at other times they occur irregularly distributed throughout strata of finer materials. At the base of the Howlett House bluff on the James River opposite Farrar Island there is a conglomerate bed 30 feet in thickness of large and small cobbles and pebbles in a matrix of coarse arkosic sand, the whole locally indurated.

Although sands predominate in the Patuxent formation, clays are not altogether absent. The beds of sand occasionally pass into clay deposits while in other places the sand and clay beds are interstratified. The sandy clays frequently contain great quantities of lignitic material. In cutting the Dutch Gap canal on the James River a log of lignite about 60 feet in length and 10 inches in diameter is said to have been taken out. The Patuxent clays are seldom highly colored, so that they can generally be very readily distinguished from the variegated clays of the Patapsco formation. In the vicinity of Dutch Gap there are irregular masses of dark-colored clay embedded in the sandy strata. Some of these are several feet in diameter and are decidedly angular, showing that they were only transported a short distance. Many fine plant impressions frequently occur in them. The sands are almost invariably cross-bedded.

Paleontologic character.—Although the Patuxent deposits are in general unfossiliferous because of their coarse character, nevertheless a large flora has been collected from clay balls and lenses and the more argillaceous sands. This flora has been elaborated by Professors Ward and Fontaine in various publications of the U. S. Geological Survey and is undergoing revision by the writer at the present time.

It includes a large element made up of survivors from the older Mesozoic and is rich in species and individuals referred to the fern genera *Cladophlebis* and *Onychiopsis*. A variety of cycad fronds testify to the abundance of this type of plant and is emphasized by the presence of numerous silicified trunks in the Maryland area. Perhaps the most striking of the cycad remains are the splendid fronds referred to the genus *Dioonites* which are extremely abundant in the Dutch Gap region. Other forms of cycads present include species of *Podozamites, Zamiopsis, Nilsonia, Ctenis, Ctenophyllus*, most of which are confined to the older Potomac and do not occur in the Patapsco deposits although some of them occur in the Arundel formation in Maryland.

Among the conifers are species of *Baiera, Brachyphyllus, Sphenolepis, Frenelopsis, Nageiopsis, Arthrotaxopsis* and *Cephalotaxopsis*, representative of various subfamilies which in the modern flora are largely natives of other continents. Supposed Angiosperms, the most ancient known, are represented by the archaic genera *Rogersia, Proteaephyllum,* and *Ficophyllum*, which may well represent the foliage of some Lower Cretaceous member of the Gnetales and not angiospermous plants, a point not yet definitely settled. [See plates 1 and 2 for some of the plants found in the Dutch Gap area.] [See localities 1-6 for Lower Cretaceous exposures.]


SERIES
STAGE
NEW JERSEY
DELAWARE
MARYLAND
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
ALABAMA
PLEISTOCENE
PLIOCENE
UPPER
LOWER
MIOCENE
UPPER
MIDDLE
LOWER
MESSIN-IAN
TORTONIAN
SERRA-VALIAN
LANGH-IAN
BURDIGALIAN
AQUI-TAINIAN
OLIGOCENE
UPPER
LOWER
CHATTIAN
RUPELIAN
CHICKASAWHAN
VICKSBURGIAN
Cohansey Formation
Kirkwood Formation
Old Church(?) Formation
Columbia Formation
Choptank Formation
Calvert Formation
Kirkwood Formation
Old Church(?) Formation
Columbia Formation
Eastover Formation
Cobham Bay Member
Claremont Manor Member
St. Marys Formation
Windmill Point Mbr.
Little Cove Point Mbr.
Conoy Member
Choptank Formation
Boston Cliffs Mbr.
St. Leonard Mbr.
Drumcliff Mbr.
Calvert Formation
Plum Point Member
Fairhaven Member
Old Church Formation
Norfolk Formation
Chowan River Formation
Yorktown Formation
Moore House Mbr.
Morgarts Beach Mbr.
Rushmere Mbr.
Sunken Meadow Mbr.
Eastover Formation
Cobham Bay Member
Claremont Manor Member
St. Marys Formation
Choptank Formation
Calvert Formation
Old Church Formation
Norfolk Formation
James City Formation
Waccamaw Formation
Chowan River Formation
Yorktown Formation
Moore House Mbr.
Morgarts Beach Mbr.
Rushmere Mbr.
Sunken Meadow Mbr.
Eastover Formation
Cobham Bay Member
Claremont Manor Member
Pungo River Formation
Belgrade Formation
Pollocksville Mbr.
Haywood Landing Mbr.
River Bend Formation
Socastee Formation
Canepatch Formation
Waccamaw Formation
Bear Bluff Formation
Raysor Formation
Coosawhatchie Clay Member
Hawthorn Formation
Edisto Formation
Cooper Marl
Ashley Member
Raysor Formation
Coosawhatchie Clay
Marks Head Formation
Hawthorn Formation
Tampa Formation
Suwannee Limestone
Bridgeboro Limestone
Bumpnose Limestone
Citronelle Formation
Chickasawhay Limestone
Bryam Formation
Marianna Limestone
Red Bluff Formation

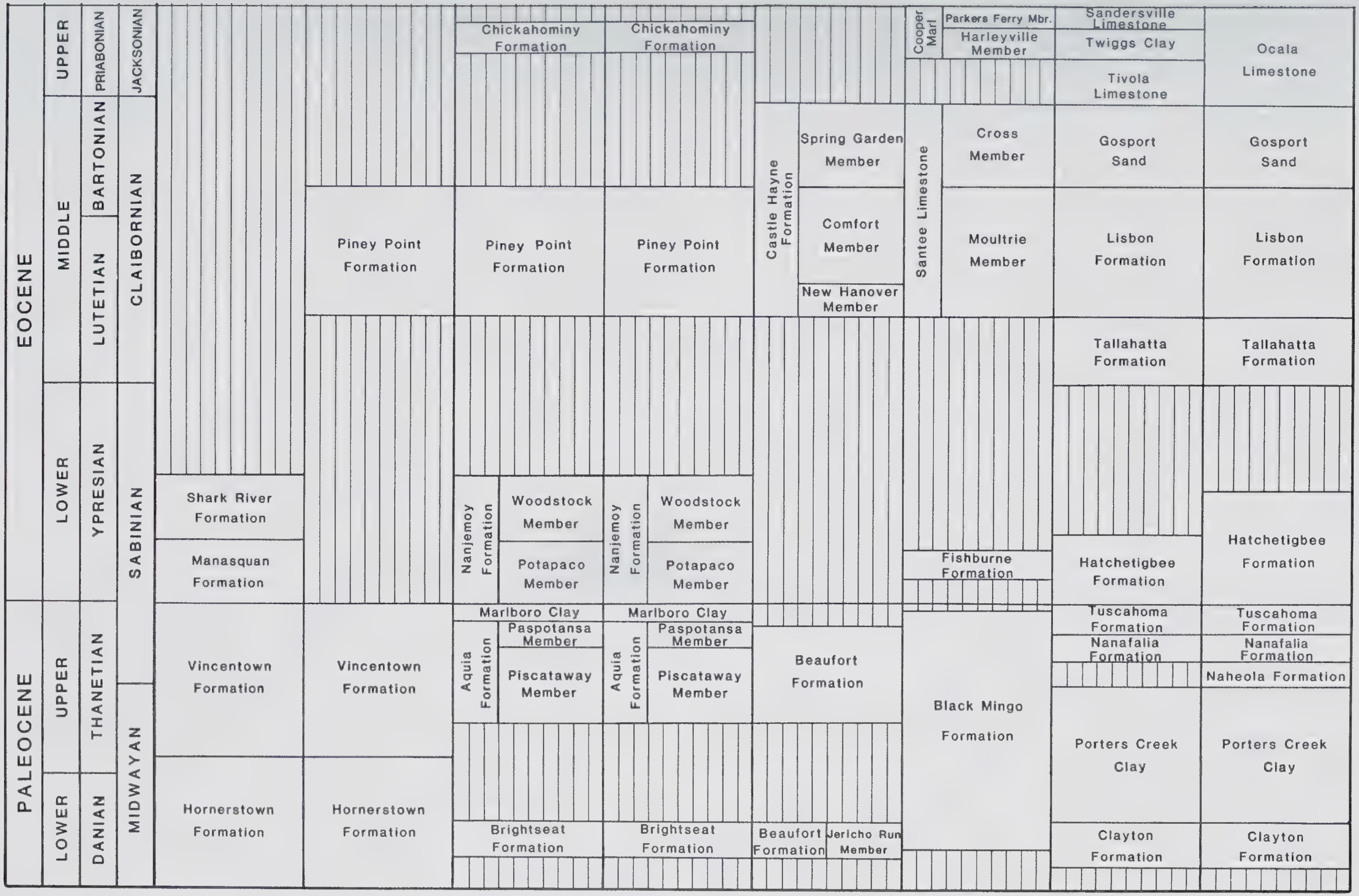
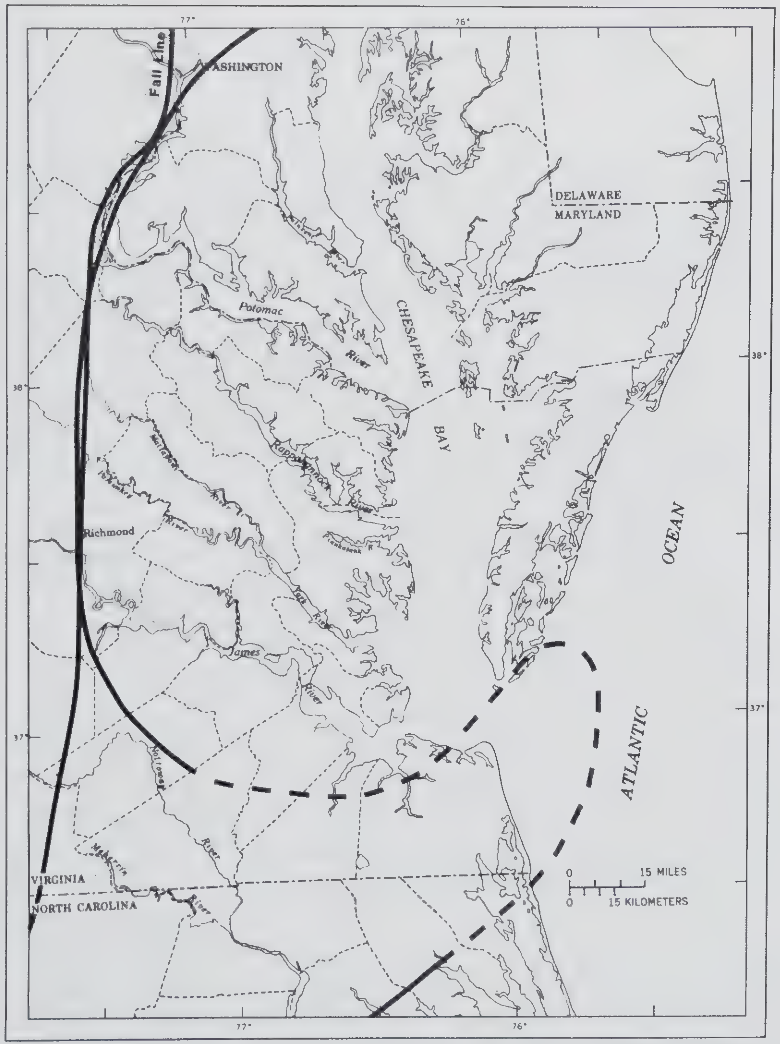
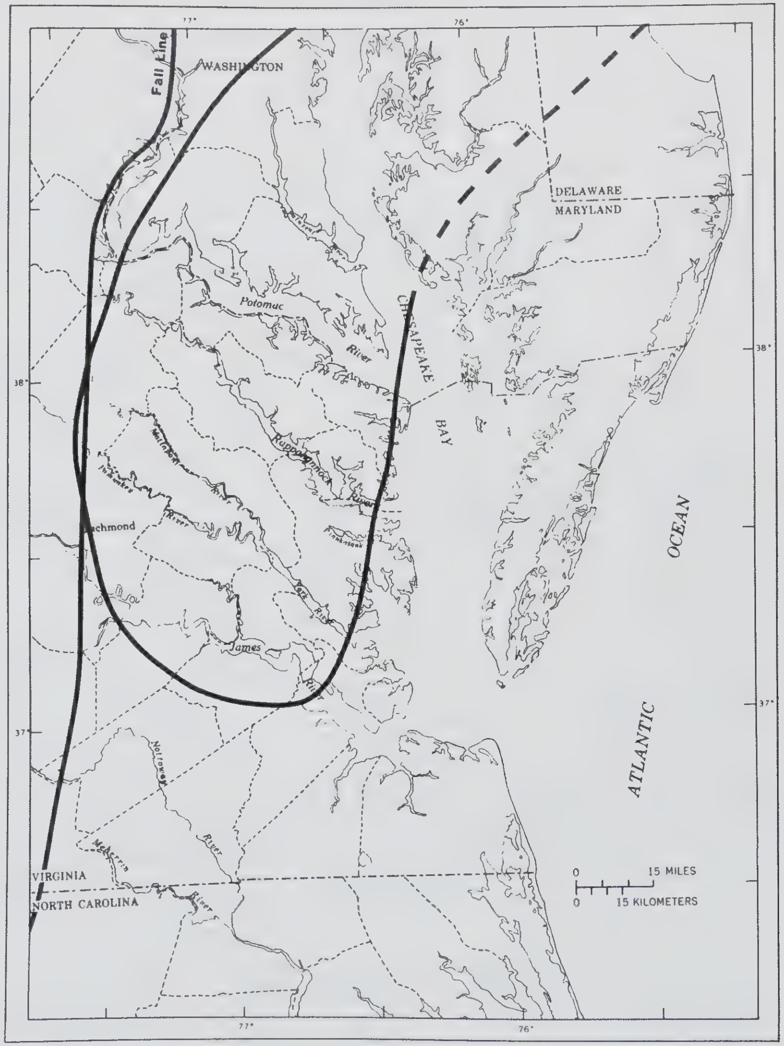


FIGURE 2. Correlation chart showing Tertiary units from New Jersey to Alabama.



Late Paleocene Aquia Formation

FIGURE 3. Areal extent of the late Paleocene depositional basin of the Aquia Formation in the Salisbury Embayment. Dashed line indicates area where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972)



Late Paleocene Marlboro Clay

FIGURE 4. Areal extent of the late Paleocene depositional basin of the Marlboro Clay in the Salisbury Embayment. Dashed line indicates area where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).

Pamunkey Group

The stratigraphy of the central Virginia Coastal Plain has been the subject of attention since the work by W. B. Rogers in the 1830s. Most late work consisted of paleontological descriptions. Darton (1891) identified the Pamunkey River exposures as typical of those glauconitic units that he termed the Pamunkey Formation and later mapped (Darton, 1894, 1896). Work by Clark (1896a, b) and Clark and Martin (1901) refined and modified the concept of the Pamunkey Formation and raised it to group status, while dividing it into formations and members. Darton (1911, 1948, 1951) accepted this stratigraphic revision and extensively mapped the formations included in the Pamunkey Group. Clark and Miller (1912) extended their stratigraphic work into the Virginia Coastal Plain, giving sections and faunal lists for outcrops on all the major rivers.

Aquia Formation

The term Aquia, as a term for a stratigraphic unit, was first introduced by Clark (1896a, b) as the Aquia Creek Stage for beds that crop out in the vicinity of Aquia Creek, Stafford County, Virginia. The concept of the unit was soon revised, and it was renamed the Aquia Formation by Clark and Martin (1901). Two members, the Piscataway and Paspotansa, were recognized by the authors. Bennett and Collins (1952) restricted Clark and Martins' (1901) earlier definition of the Aquia when beds placed in Zone 1 by Clark were designated the Brightseat Formation. The Aquia is further characterized by a description of its members. See Figure 2, 3.

Piscataway Member

The Piscataway Member of the Aquia Formation was named by Clark and Martin (1901) from exposures along Piscataway Creek, Prince Georges County, Maryland. It included seven "Zones," which were traceable along the Potomac River in the type area of the Aquia. "Zone 1" of Clark and Martin (1901) has since been recognized as a distinct unit by Bennett and Collins (1952) and was termed the Brightseat Formation. Ward (1985) restricted the Piscataway to "Zones" 2-5. The beds assigned to the Piscataway consist of clayey, silty, poorly sorted, glauconitic sands, which contain large numbers of macrofossils, principally mollusks, concentrated in beds of varying thicknesses and cemented at several intervals into locally traceable indurated ledges. Large bivalves, including *Cucullaea, Ostrea, Dosiniopsis,* and *Crassatellites* (Plate 3), are the most conspicuous taxa.

The Piscataway Member crops out on the James River 1.0 mile above the Turkey Island Cutoff (Locality 7). This is the only known locality on the James. The Cretaceous-Aquia contact is at river (sea level) and is marked by a layer of cobbles.

On the basis of ostracodes and planktonic foraminifers, Hazel (1969) placed the Piscataway in the *Globorotalia pseudomenardii* Subzone of the *Globorotalia velascoensis* Zone and in the Upper Landenian Stage.

Paspotansa Member

The Paspotansa Member of the Aquia Formation was named and described by Clark and Martin (1901). As originally defined, the Paspotansa included "Zones 8 and 9" of Clark and Martin (1901). It was recommended that "Zones 6 and 7" also be included in the Paspotansa by Ward (1985). The Paspotansa consists of fine to very fine, silty, well-sorted micaceous, glauconitic and quartzose sand in massive or very thick beds. This texture is strikingly different from the underlying, poorly sorted, clayey, shelly, glauconitic and quartzose sand of the Piscataway member. The Paspotansa is usually unconformably overlain by a gray (N7, when fresh), tough clay termed the Marlboro Clay. Where the Marlboro is absent, the well-sorted, fine sands of the Paspotansa may be distinguished from the overlying, clayey, highly bioturbated, poorly sorted glauconitic sands of the Potapaco Member of the Nanjemoy Formation. Massive glauconitic sands containing considerable numbers of large *Turritella* in thin beds or lenses characterize the Paspotansa.

The Paspotansa Member is well exposed along the James River and crops out intermittently from Shirley Plantation (Locality 8) to below Hopewell (Locality 10). It contains large numbers of macrofossils, principally mollusks, often concentrated in thin beds or lenses. Preservation of macrofossils at the James River localities is poor and consists mainly of molds and casts. The most common taxa are shown on Plate 4.

Gibson and others (1980) identified the Paspotansa in a core taken in Westmoreland County, Virginia, and placed the entire member in nannoplankton zone NP9.

MARLBORO CLAY

Clark and Martin (1901, p. 65) first applied the term "Marlboro clay" to sediments included in "Zone 10" of Clark (1896b, p. 42). The name was derived from exposures of that unit near Upper Marlboro, Prince Georges County, Maryland. Clark and Martin (1901) considered this unit to be the basal unit of the Potapaco Member of the Nanjemoy Formation. Darton (1948, 1951) considered the Marlboro as the basal bed of the Nanjemoy. Glaser (1971) formally proposed the elevation of the Marlboro Clay to formational rank, thus restricting the original concept of the Nanjemoy Formation and, more specifically, the Potapaco Member. See Figure 4 for the Marlboro Basin.

Glaser (1971, p. 14) characterized the Marlboro as "a silvery-gray to pale-red plastic clay interbedded with much subordinate yellowish-gray to reddish silt." Ward (1985) and Glaser (1971) pointed out that both the lower and upper contacts of the Marlboro are sharp and nongradational and probably represented at least a brief hiatus between the underlying and overlying units.

The Marlboro Clay can be seen below the mouth of Baileys Creek, downriver of Hopewell (Locality 10). There 10.0 feet of Marlboro overlies 17.5 feet of the Paspotansa Member.

Gibson and others (1980) and Frederiksen (1979) documented pollen and dinoflagellate data which suggest a very late Paleocene or a very early Eocene age assignment for the Marlboro. Ward (1985) considered the Marlboro to be an upper Paleocene unit.

NANJEMOY FORMATION

Beds now included in the Nanjemoy Formation were first studied in detail by Clark (1896b), who divided them, along with those beds now included in the Aquia Formation, into "Zones." The "Zones" above the Aquia Creek Stage of Clark (1986b) were numbered 10 through 17. "Zone 17" was described as the Woodstock Stage. Clark and Martin (1901) revised this terminology and placed their "Zones 10 through 17" in the "Nanjemoy Formation or Stage." The Nanjemoy was divided into the "Potapaco Member or substage," including "Zones 10 through 15," and the "Woodstock Member or substage," including "Zones 16 through 17." Clark and Miller (1906) dropped the stage and substage terminology and referred only to the Aquia and Nanjemoy Formations. Clark and Miller (1912) continued this usage and retained both in formational status. Beds along the Pamunkey and James Rivers which are of middle Eocene age were lumped in the Nanjemoy by Clark and Miller (1912). These younger beds are equivalent to the Piney Point Formation of Otton (1955). Ward (1985) recognized the Piney Point on the Pamunkey and James Rivers and differentiated it from the Nanjemoy.

Potapaco Member

The Potapaco Member of the Nanjemoy Formation was described by Clark and Martin (1901) and includes "Zones 10-15." Work by Ward (1985), principally on the Pamunkey River, but with supplemental sections on the James, Mattaponi, Rappahannock, and Patuxent Rivers, identified a stratigraphic sequence of beds in the Potapaco. There are no known outcrops of Potapaco on the James River but the unit probably underlies the

Woodstock Member in the Hopewell area. (See Figure 5 for the Potapaco Basin.)

Bed A—Non-bedded Potapaco. Bed A is found on the Pamunkey, Potomac, Rappahannock, and Mattaponi Rivers. It consists of a clayey, silty, fine glauconitic sand containing scattered, small mollusks including *Vericardia potapacoensis* Clark and Martin (1901). The bed is estimated to be 15 to 20 feet (4.6 to 6.1 m) thick, and in most places it unconformably overlies the Marlboro Clay. Bed A is distinguishable from Bed B by the former's darker color, lack of bedding, and less clayey texture. Calcareous fossils are generally leached, leaving only molds and casts. Mollusks, in general, are poorly preserved, but where present, are low in diversity (Plate 5). Dinoflagellates found in Bed A indicate an early Eocene age (Ward, 1985).

Bed B—Bedded Potapaco. Bed B is easily recognized by accumulations of the small bivalve, *Venericardia potapacoensis* Clark and Martin (1901) in vast numbers along numerous, discontinuous, thin bedding planes. The exact thickness of Bed B is difficult to determine because of poor outcrops, but it ranges from only a few feet to more than 15 feet (4.6 m). The sediment in Bed B consists of olive-gray (5Y 4/1), very clayey, glauconitic sand to sandy clay. Bed B can be seen along the Pamunkey River from 0.65 miles (1.04 km) above Normans Bridge to Dabneys Millpond.

The molluscan assemblage of Bed B is dominated by *Venericardia potapacoensis* Clark and Martin (1901). Other mollusks present in Bed B occur in small numbers (Plate 5). Along the Pamunkey River, Bed B contains a dinoflagellate flora correlative to what has been called NP10 or 11 (Ward, 1985).

Bed C—Burrowed Potapaco. Above the thin-bedded clayey sand of Bed B is a sequence of sandy clay to clayey sand that is easily recognizable by its intensely burrowed appearance. Bedding, if it were ever present, has been obscured by bioturbation except along a few very thin planes. Along those surfaces sedimentation appears to have been interrupted and is marked by at least local diastems, by a concentration of glauconitic sand, and by glauconite-filled burrows extending down into the underlying sediment. The dominant lithic characteristic of Bed C is its very clayey texture, with interspersed grains of fine- to medium-sand-sized glauconite in a grayish-orange-pink (5YR 7/2) clay matrix. Bed C overlies Bed B with no distinct contact between the two, suggesting a gradation from one environmental regime to another. On the Pamunkey River, Bed C is overlain by a thin bed (Bed D), 1.5 to 3.0 feet thick (0.5 to 0.9 m) of clayey, glauconitic sand marked by a series of boulder-sized indurated blocks.

Bed C contains a nondiverse assemblage (where preserved) consisting of a few *Corbula, Lucina*, and *Cadulus* that offer little evidence of age. On the basis of the dinoflagellate flora, Bed C correlates with calcareous nannoplankton zone NP 10 or 11 (Ward, 1985).

Bed D—Concretion-bed Potapaco. Bed D crops out only along the Pamunkey River above and below the mouth of Totopotomoy Creek and consists of 1.5 to 2.0 feet (0.5 to 0.6 m) of clayey, very glauconitic sand. Both its upper and lower contacts are marked by abrupt changes in lithology and color and contain concentrations of phosphate pebbles, quartz, and wood. The high glauconite content of Bed D makes it easily differentiated from the lighter colored clays of Bed C and the less glauconitic silty sand of the basal portion of the overlying Woodstock Member. The bed is marked by a line of cobble- to boulder-sized concretions that occur in the middle of the unit.

Mollusks in Bed D, in the small area they could be studied, are very poorly preserved, small and fragmentary, and include *Corbula, Lucina, Venericardia,* and *Cadulus*. The dinoflagellate assemblage indicates an equivalency with calcareous nannoplankton zones NP10 and 11 (Ward, 1985). See Plate 5 for the Potapaco molluscan fauna.

Woodstock Member

The Woodstock Member of the Nanjemoy Formation was named by Clark and Martin (1901, p. 66). The term Woodstock had previously been used by Clark (1895, 1896a, b) to describe the Woodstock Stage, a unit defined principally on its fauna. Clark and Martin (1901) described the Woodstock Member as consisting of their "Zones 16 and 17." See Figure 6 for the Woodstock Basin.

The Woodstock consists of olive-black (5Y 2/1), very fine, well-sorted, silty glauconitic sands. It conformably overlies the Potapaco Member and is unconformably overlain either by the Piney Point Formation (middle Eocene), where present, or by younger beds. The Woodstock may be distinguished from the underlying Potapaco by its fine-textured, micaceous, massive appearance, in contrast to the very clayey, poorly sorted, bioturbated texture of the underlying Potapaco. The overlying Piney Point is coarser textured, clayey, poorly sorted, and more calcareous.

The Woodstock is exposed along the James River in the vicinity of Tar Bay where it crops out in the sharply-cut ravines (Locality 11). The Piney Point directly overlies the Woodstock in the surrounding area, separated by a sharp, easily distinguished unconformity.

The Woodstock contains a moderately diverse molluscan fauna (Plate 6). Dinoflagellate and calcareous nannofossil data from the Woodstock Member indicate an equivalence with NP 12 (Ward, 1985).

Carbonized wood and nuts are especially abundant in the lower section of the Woodstock (Mazer and Tiffney, 1982).

PINEY POINT FORMATION

The Piney Point Formation, where fresh, is an olive-gray (5Y 4/1), clayey, poorly sorted, very glauconitic, highly fossiliferous sand first described from cuttings taken in a well at Piney Point, St. Marys County, Maryland, by Otton (1955). It may be seen along the Pamunkey River to unconformably overlie the Woodstock Member of the Nanjemoy Formation. Good exposures of the contact between the two units occur almost continuously along the Pamunkey River to below the ruins of the Newcastle Bridge. Burrowing of the Woodstock surface is intense.

The Piney Point along the Pamunkey River is overlain, in places, by an upper Oligocene unit, the Old Church Formation, and in other places by the Calvert Formation where the Old Church was not deposited or has been beveled off. The contact between the Piney Point and Old Church is sharp and is marked by a basal lag of shell, bone, and pebbles. Ward (1985) proposed that the outcrops at Horseshoe and 0.5 miles to the west be considered hypostratotypes or reference sections of the Piney Point. On the James River the Piney Point Formation is exposed in ravines in the Tar Bay area.

The Piney Point is the equivalent of the Castle Hayne Formation in North Carolina and the Santee Limestone in South Carolina. *Cubitostrea sellaeformis* (Conrad, 1832) is common in the middle Eocene (Claibornian Stage) interval over this wide geographic area as are several mollusks (Plate 7). This correlation and age assignment are in agreement with dinoflagellate data, ostracode data, and planktonic foraminifer data (Ward, 1985). Calcareous nannoplankton present in the Piney Point indicate a placement in Zone NP16 (DiMarzio, oral communication). See Figure 7 for the Piney Point Basin.

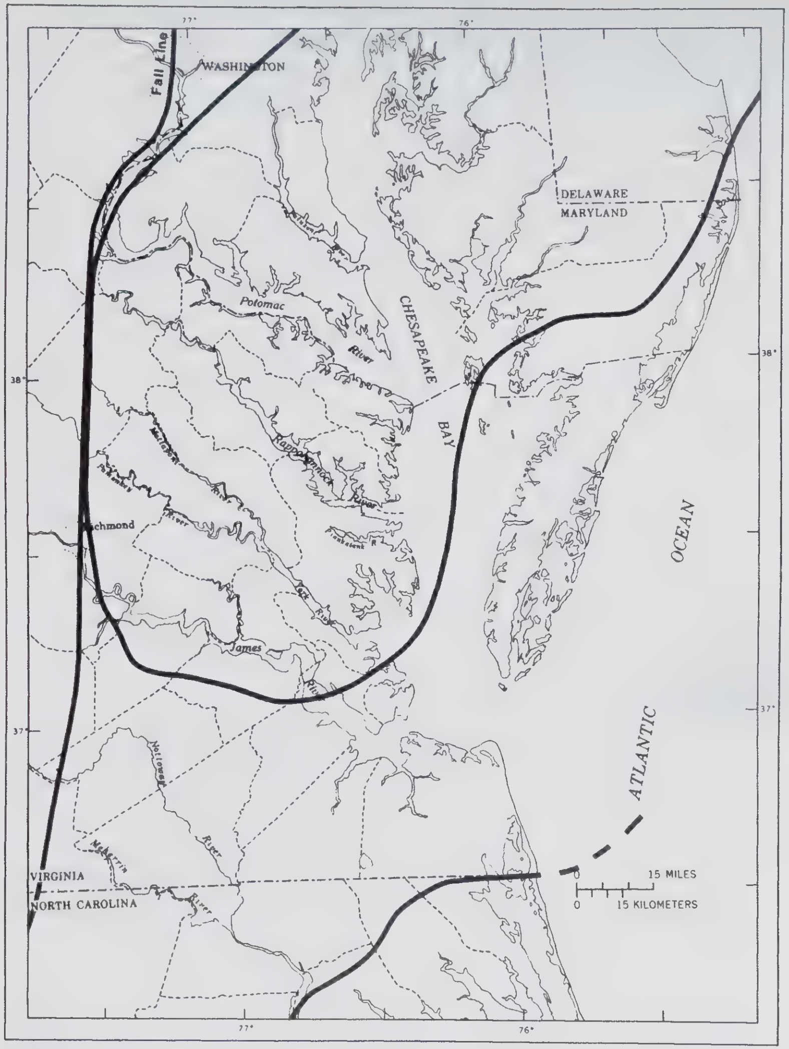


FIGURE 5. Areas extent of the early Eocene depositional basin of the Potapaco Member of the Nanjemoy Formation in the Salisbury Embayment. Dashed line indicates where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).

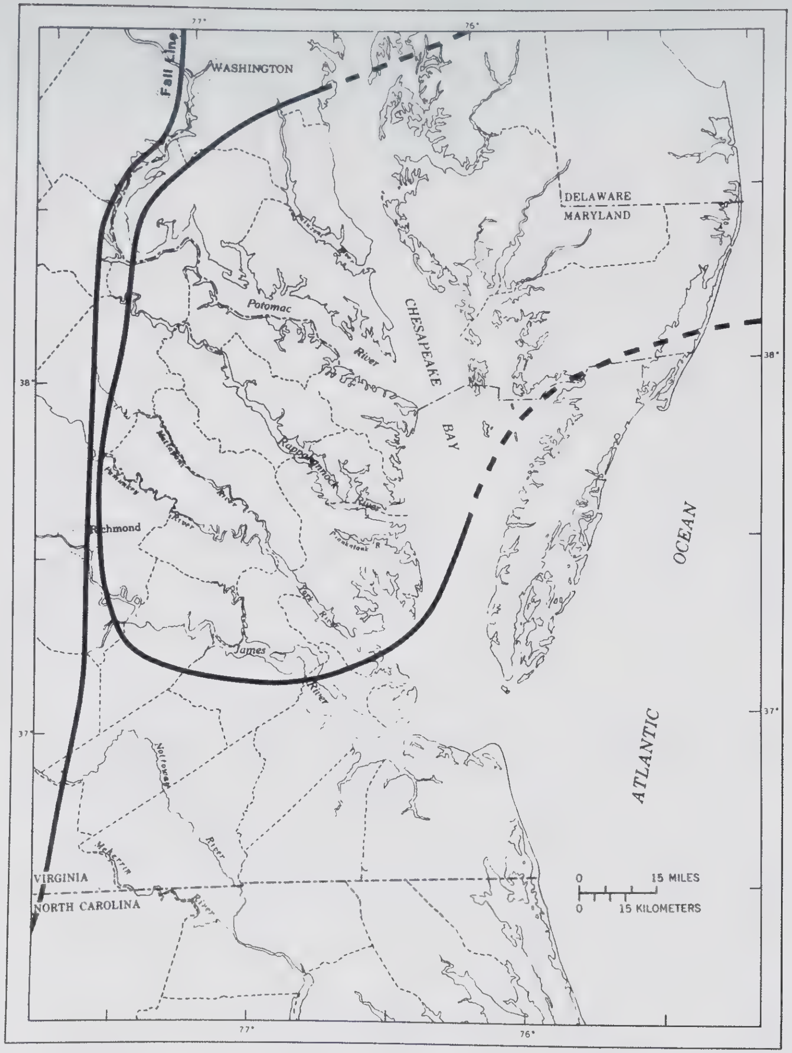


FIGURE 6. Areal extent of the early Eocene depositional basin of the Woodstock Member of the Nanjemoy Formation in the Salisbury Embayment. Dashed line indicates where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).

CHESAPEAKE GROUP

The term Chesapeake Formation was introduced by Darton (1891) for a series of beds of sands, clays, marls, diatomaceous clays, and shell fragments in southeastern Maryland and Virginia. Dall and Harris (1892) elevated the unit to group status and included all stratigraphically equivalent beds at the same horizon from Delaware to Florida. Shattuck (1902, 1904) subdivided the Chesapeake Group in Maryland into (in ascending order) the Calvert Formation, the Choptank Formation, and the St. Marys Formation. Clark and Miller (1906) named and described the Yorktown Formation in Virginia. Mansfield (1944) included beds along the Chowan River in Bertie County, North Carolina, in the Yorktown Formation. Blackwelder (1981) named those beds the Chowan River Formation. Ward (1985) named the Old Church Formation and included that unit and the Chowan River Formation in the Chesapeake Group. (Ward, 1984)

OLD CHURCH FORMATION

The upper Oligocene beds on the Pamunkey River consisting of grayish-olive (10Y 4/2), clayey, quartz sands containing minor amounts of reworked glauconite were named the Old Church Formation by Ward (1985). $CaCO_3$ content is high due to shell fragments as well as to large numbers of foraminifers and ostracodes within the unit, both primary and reworked. Aragonitic molluscan fossils are commonly leached, while calcitic taxa are preserved and consist of small pectens and oysters. The formation contains irregular, indurated masses that occur along the river as boulder-sized concretions. In Virginia, the Old Church is known in natural surface exposures only from the Pamunkey River, where it crops out from above Horseshoe to below the mouth of Matadequin Creek. The exposure on the right bank of the Pamunkey at Horseshoe was designated the type section of the Old Church by Ward (1985). The Old Church Formation has not been identified in outcrop on the James River, but its presence in pits along the Chickahominy River at Bottoms Bridge makes it likely to extend as far south as the James. See Figure 8 for the Old Church Basin.

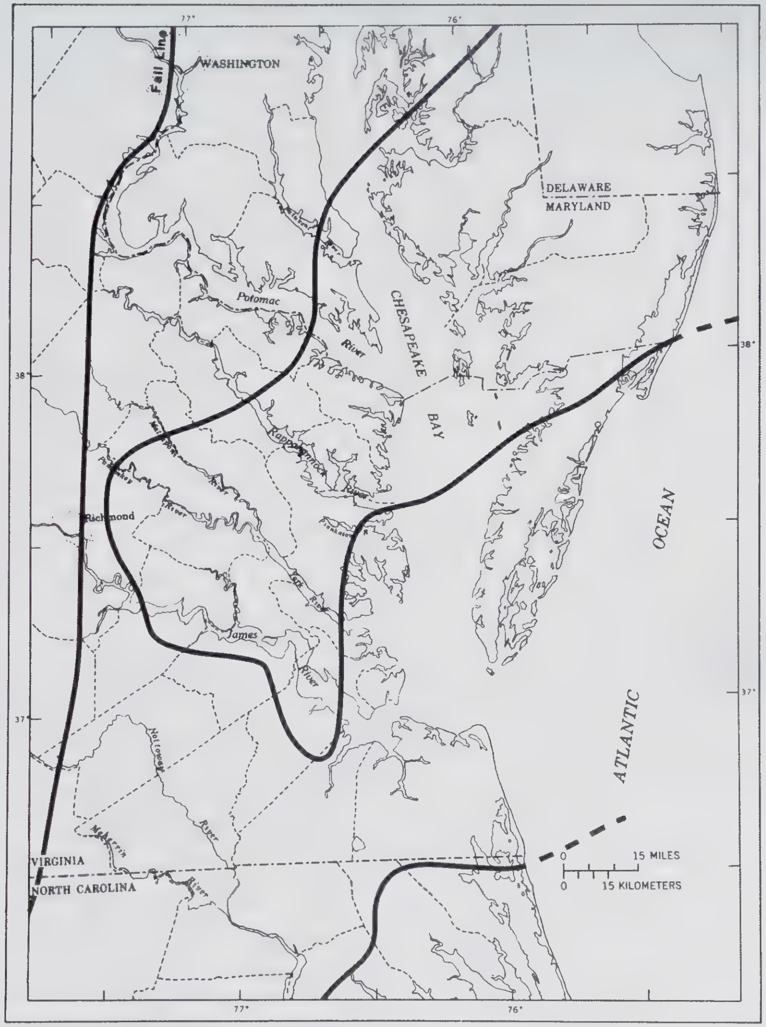
Because of basic, though minimal, differences of opinion as to the age of the Old Church Formation, the precise correlation of that unit to equivalent beds to the south have been debated. The consensus of paleontological data, including mollusks, ostracodes, foraminifers, pollen, and dinoflagellates, brackets the unit in the interval embracing the late Oligocene (Ward, 1985).

Molluscan assemblages of the Old Church Formation indicate a close affinity with both the upper River Bend and the Belgrade Formations in North Carolina but lack the diversity of those units (Plate 8). It does contain elements of the temperate Chesapeakean fauna to follow.

CALVERT FORMATION

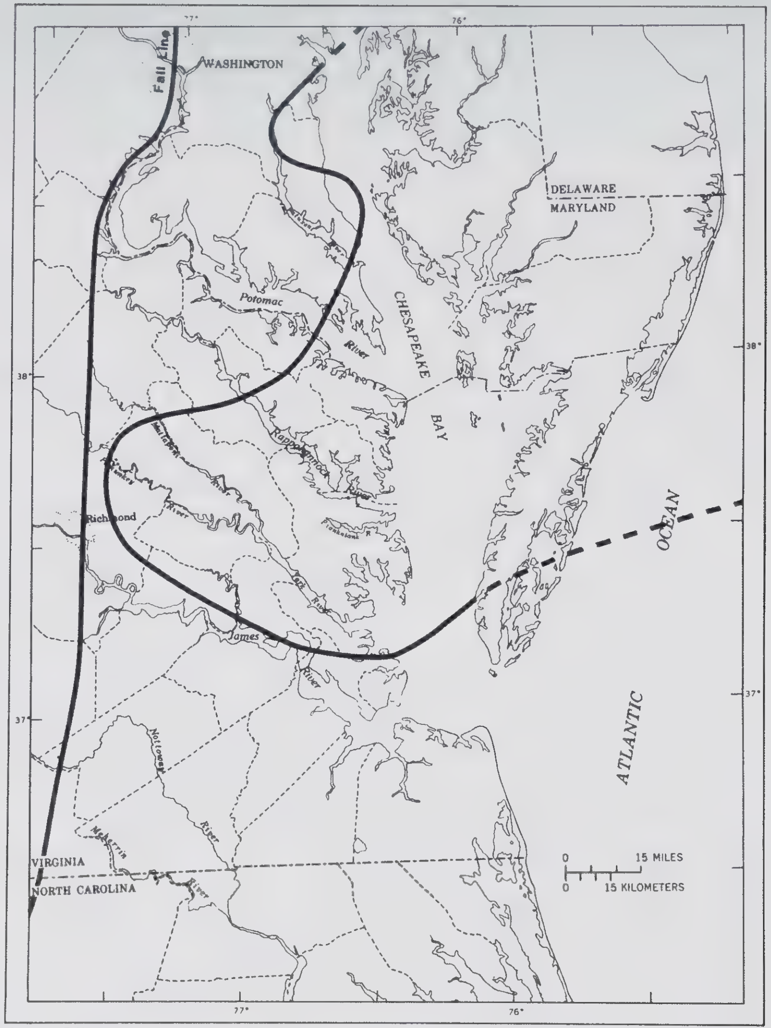
The Calvert Formation was named and described by Shattuck (1902, 1904) for Miocene beds exposed along the Calvert Cliffs in Calvert County, Maryland. Sections for the Calvert were given by that author, principally along the Chesapeake Bay, but he described a few other localities in scattered areas of Maryland. The Calvert Formation in Virginia was first mentioned by Clark and Miller (1906) and it was mapped in the Richmond area by Darton (1911).

Clark and Miller (1912) documented the extent of the Calvert and other Coastal Plain units in Virginia.



Middle Eocene **Piney Point Formation**

FIGURE 7. Areal extent of the middle Eocene depositional basin of the Piney Point Formation in the Salisbury Embayment. Dashed lines indicate area where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).



Late Oligocene **Old Church Formation**

FIGURE 8. Areal extent of the upper Oligocene depositional basin of the Old Church Formation in the Salisbury Embayment. Dashed lines indicate area where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).

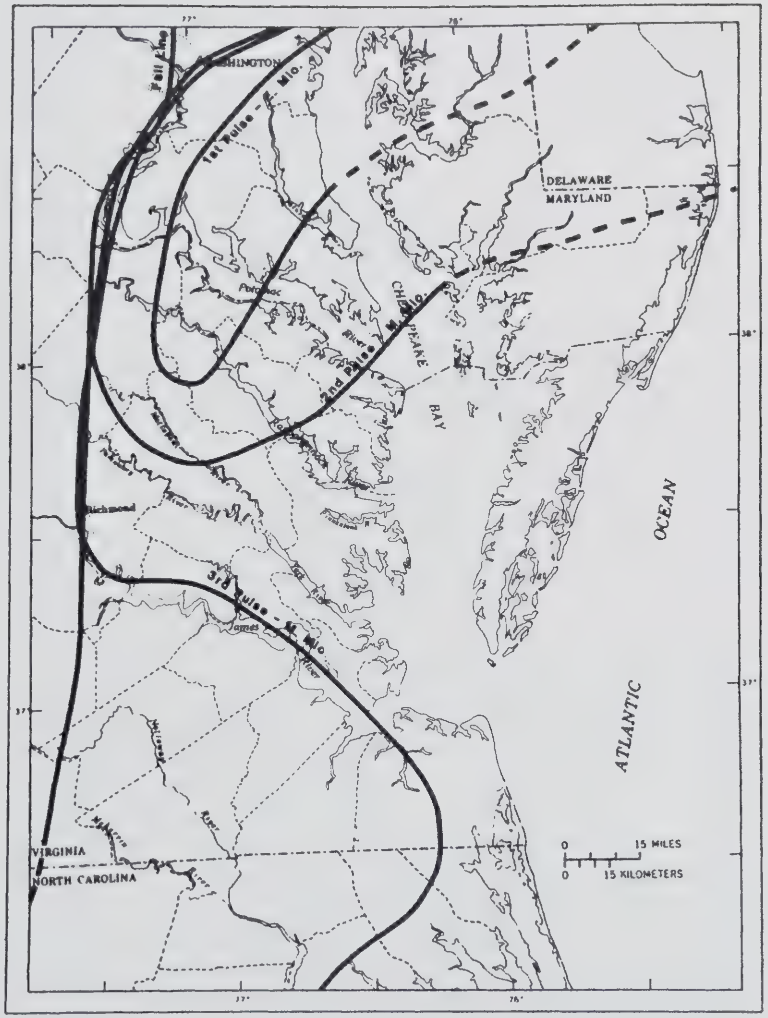


FIGURE 9. Areal extent of the early Miocene and early middle Miocene depositional basin of the Calvert Formaton in the Salisbury Embayment. Dashed lines indicate area where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).

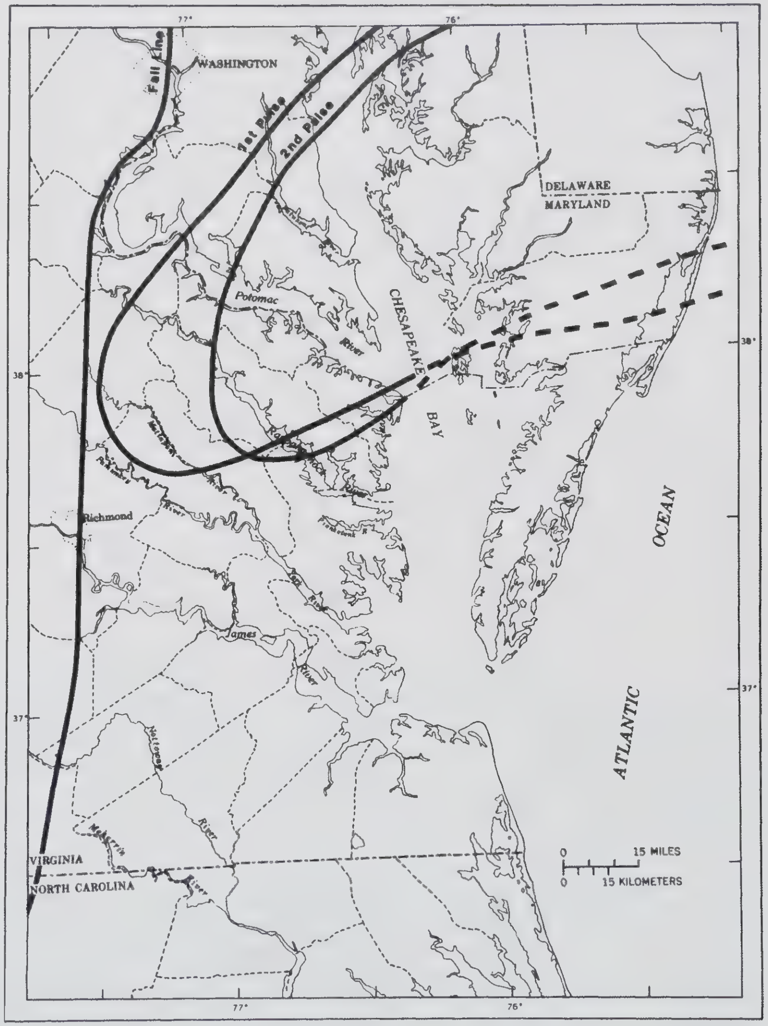


FIGURE 10. Areal extent of the middle Miocene depositional basin of the Choptank Formation of the Salisbury Embayment. Dashed lines indicate area where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).

Fairhaven Member

The Fairhaven Member of Shattuck (1904) includes Beds 1, 2, and 3. Bed 2 is the basal transgressive sand that accumulated during the second Calvert pulse or sea level rise resulting in Bed 3-A. Bed 3-B is a massive series of diatomaceous clays that includes most of the thickness of the Fairhaven. Beds of the Fairhaven crop out as far south as the Mattaponi River.

Plum Point Marl Member

The Fairhaven Member is overlain unconformably by a series of shelly sands interbedded with diatomaceous clays grouped under the term Plum Point Marl Member. This series contains at least four pulses: one pulse is Bed 4-9 of Shattuck (1904), another pulse is Bed 10-11, a third pulse is Bed 12-13, and a last pulse is Bed 14-16. By means of diatoms, and occasionally mollusks, correlation with the Beds visible on the Chesapeake Bay is possible in Virginia. On the Pamunkey River, equivalents of Bed 14-15 have been identified by diatoms at Elsing Green (G. W. Andrews, personal communication). Molds and casts of mollusks are present in the Calvert on the Pamunkey River and in the Richmond area. Those taxa can be seen on Plate 9.

The area of the James where the Calvert Formation is projected to descend to sea level is in the Tar Bay area and downriver where Pleistocene erosion has obscured the stratigraphy. See Figure 9 for the Calvert Basin.

CHOPTANK FORMATION

The Choptank Formation was named and described by Shattuck (1902, 1904) for Miocene beds exposed along the Calvert Cliffs in Calvert County, Maryland. Sections of the Choptank, like those for the Calvert, were given along the Chesapeake Bay with only a few supplemental sections from other areas. The Choptank was originally composed of “Zones 16 through 20” of Shattuck. Ward (1984) recommended the placement of Beds 14, 15, and 16 in the Calvert Beach Member, as defined by Gernant (1970), and expanded by Ward (1984). The Calvert Beach Member of Gernant is actually the upper unit of the Plum Point Member. Bed 20, or the Conoy Member of Gernant (1970), was recommended removed from the Choptank by Blackwelder and Ward (1976) and placed in the St. Marys.

The Choptank consists of three members (in ascending order): Drumcliff, St. Leonard, and Boston Cliffs. The Boston Cliffs Member is represented by a diatomaceous clay-silt at several localities in downtown Richmond (Locality 6). No mollusks are present in these fine-grained sediments. See Figure 10 for the Choptank Basin.

ST. MARYS FORMATION

The St. Marys Formation was named and described by Shattuck (1902, 1904) for Miocene beds exposed along the Calvert Cliffs in Calvert County, Maryland, and along the St. Marys River, St. Marys County, Maryland. None of the beds included in the St. Marys are known to extend southeastward as far as the Richmond area or the James River. The unit does crop out on the Mattaponi River at White Oak Landing, King William County (Ward, 1992, p. 28), and in the vicinity of Tappahannock on the Rappahannock River, Essex County (Ward, 1992, p. 31, 34). See Figure 11 for the St. Marys Basin.

EASTOVER FORMATION

The Eastover Formation, named for a series of beds of silty sand, clay, and shelly fine sand in the Maryland, Virginia, and North Carolina Coastal Plain (Ward and Blackwelder, 1980), consists of two members. The lower member, the Claremont Manor, is a greenish-gray (5Y 5/2), fine-grained clayey sand or sandy clay. The overlying Cobham Bay Member consists of units of fine-grained, well-sorted, very shelly sand. See Figures 12 and 13 for the Claremont Manor and Cobham Bay Basins.

Claremont Manor Member

The Claremont Manor Member was named for the extensive exposures along the James River below Upper Chippokes Creek near Claremont Manor (Ward and Blackwelder, 1980. The type locality is 1.3 km below the mouth of Sunken Meadow Creek. Surry County, Virignia (Locality 12). The Claremont Manor consists of beds of poorly sorted,

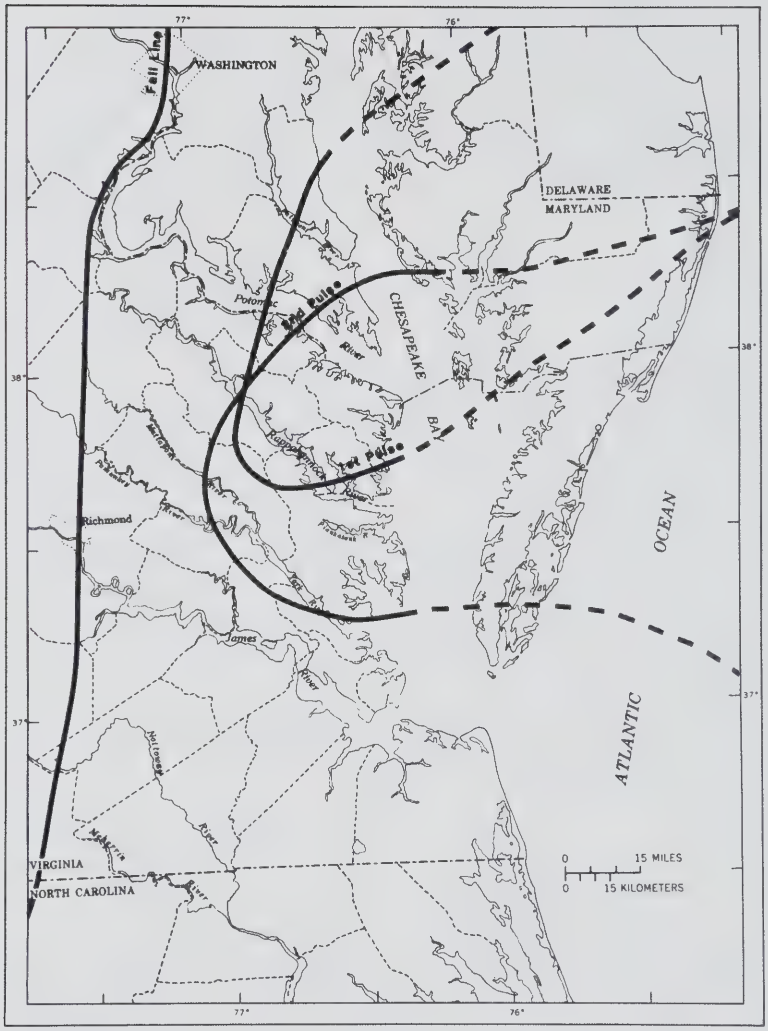


Figure 11. Areal extent of the late Miocene depositional basin of the St. Marys Formation in the Salisbury Embayment. Dashed lines indicate area where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972). Pulse 1 represents the Conoy Member and the Little Cove Point beds; Pulse 2 represents the Windmill Point beds.

coarse to fine, silty and clayey sand that fines upward in many areas to clay. The lower contact of the Claremont Manor is sharp in most places, and phosphate nodules, bone, teeth, and pebbles are present at the boundary. Clay sequences generally mark the perimeter of the Claremont Manor Basin; toward the center or eastern parts of the basin the sand content increases. Where fresh, most of these beds are greenish-gray (5 YR 5/2), but weather to an iron-stained tan (10YR 8/6). The thickest known sequence of Claremont Manor is at Claremont where 24 m occurs in the subsurface and in outcrop. The poorly-sorted, coarse, basal sand of the Claremont Manor differs from the underlying fine-grained, well-sorted shelly sand of the St. Marys Formation. The Cobham Bay Member, which overlies the Claremont Manor Member, differs in being well-sorted, less silty or clayey, and in having an abundance of well-preserved mollusks in thick beds. See Plate 10 for characteristic mollusks of the Claremont Manor. The Claremont Manor Member is probably of early Tortonian Age or late Miocene. See Figure 12 for the Claremont Manor Basin.

Cobham Bay Member

The Cobham Bay Member was named for exposures along the James River at Cobham Bay (Ward and Blackwelder, 1980). The type section is 0.8 km below Cobham Wharf, Surry County, Virginia (Locality 13). At Cobham Bay, the member reaches a thickness of 3.7 m and crops out from below Claremont Wharf to Lower Chippokes Creek. The Cobham Bay Member consists of a fine-grained, well-sorted shelly sand throughout most of its geographic extent. Only regionally, where structural or depositional features created barriers, were clays accumulated. However, these features are local and the Cobham Bay retains its clean, sandy character over most of the basin. Grayish blue (5PB 5/2) where fresh, the Cobham Bay sediments weather to a yellowish orange (10YR 8/6). Dips vary with local structural features, although the strike is approximately north-south. Throughout most of the basin, the normal seaward dip is maintained at a rate of approximately 1.0 m/km. Over most of its geographic range, the Cobham Bay unconformably overlies the Claremont Manor Member. The Yorktown Formation overlies the Cobham Bay Member along the James River from Grove Wharf, James City County, to Sunken Meadows Creek in Surry County. In Petersburg, along Lieutenant Run, the Cobham Bay can be seen underlying the Rushmere Member of the Yorktown Formation. It also underlies the Rushmere on the James below Baileys Creek (Locality 11). See Figure 13 for the extent of the Cobham Bay Basin.

The Cobham Bay Member is of late Tortonian Age (late Miocene). A radiometric date on glauconite from the lower part of Cobham Bay Member is 8.7 ± 0.4 million years (Ward and Blackwelder, 1980). *Chesapecten middlesexensis*, one of the characteristic species of the Cobham Bay Member, occurs in the *Arca* zone of western Florida. The ostracode *Aurila redbayensis* (Howe and Brown, 1935) is present in the upper part of Cobham Bay in the shallow subsurface of the eastern shore of Virginia and in the *Arca* zone of western Florida (Hazel, written communication, 1975). The *Arca* zone has been placed in planktic foraminifer zone N17 (Akers, 1972). See Plates 11 and 12 for characteristic mollusks of the Cobham Bay Member.

YORKTOWN FORMATION

The Yorktown Formation consists of a basal, very shelly, fine-grained sand unit, a shelly, poorly sorted sand unit, a very fine-grained sandy silt and clay unit, and a bioclastic sand unit. These four units, named and described by Ward and Blackwelder (1980), are the Sunken Meadow Member, the Rushmere Member, the Morgarts Beach Member, and the Moore House Member. The original description of the Yorktown Formation (Clark and Miller, 1906) did not clearly designate a type locality but included beds at Yorktown, Virginia and on the James River. The beds at Yorktown are now largely inaccessible because the cliffs have been obscured by riprap. A section near Rushmere, Isle of Wight County, was designated lectostratotype of the Yorktown Formation by Ward and Blackwelder (1980). See Figure 14 for the Yorktown Basins.

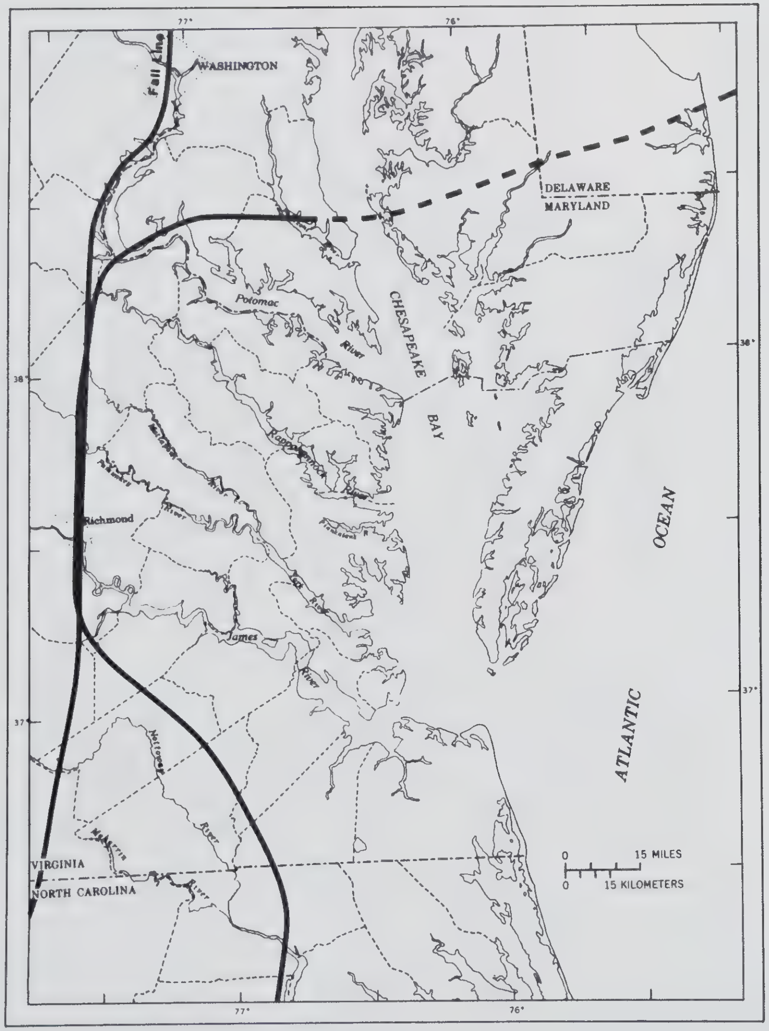


Figure 12. Areal extent of the late Miocene depositional basin of the Claremont Manor Member of the Eastover Formation in the Salisbury Embayment. Dashed lines indicate area where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).

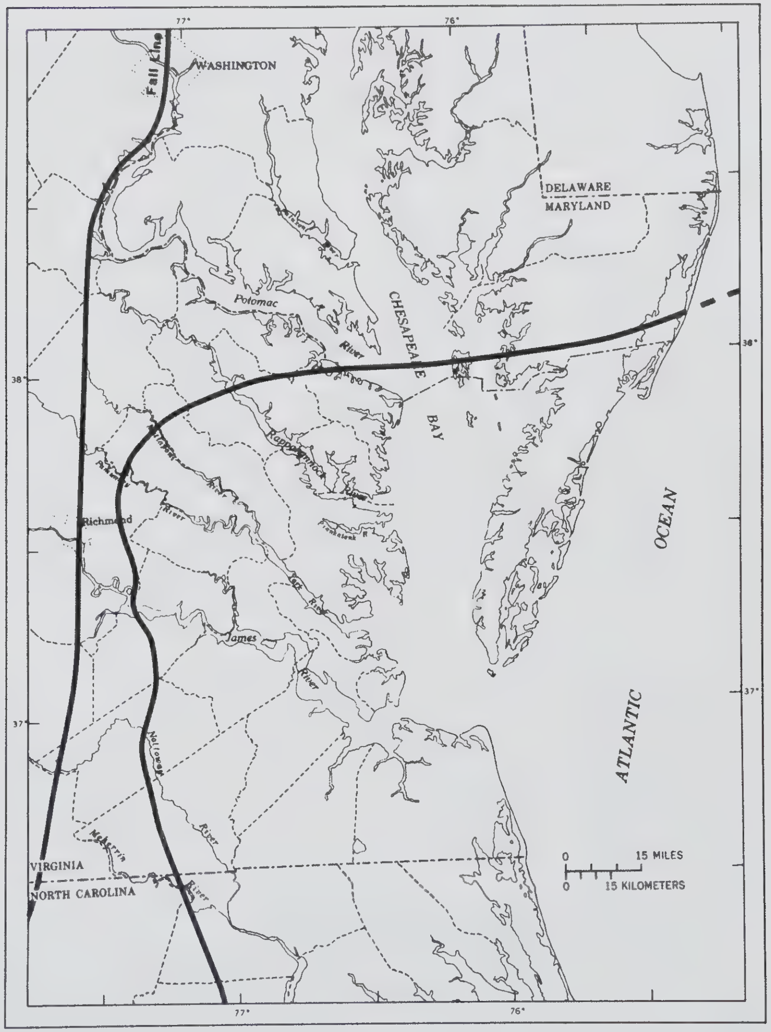


Figure 13. Areal extent of the late Miocene depositional basin of the Cobham Bay Member of the Eastover Formation in the Salisbury Embayment. Dashed lines indicate area where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).

Sunken Meadow Member

The Sunken Meadow Member consists of a basal transgressive, medium to fine, well-sorted, very shelly sand. To the west, the lower contact of the member is marked by a coarse lag deposit. To the east the basal deposits are finer and are dominated by glauconitic and phosphatic fine shelly sand.

The Sunken Meadow unconformably overlies the Cobham Bay Member of the Eastover Formation in much of Virginia, and to the south it overlies older stratigraphic units. Throughout its extent, the lower contact is well defined. The Sunken Meadow is overlapped unconformably, in most of its extent, by the Rushmere Member of the Yorktown Formation. The Sunken Meadow strikes northeast-southwest and dips at the average rate of 0.5 m/km, but thins to the west and south. The Sunken Meadow is exposed at Claremont (Locality 12), Cobham Wharf (Locality 13), and Kingsmill (Locality 14). See Plate 13 for mollusks of the Sunken Meadow Member.

Rushmere Member

The Rushmere Member consists of a poorly-sorted, silty, shelly sand. Phosphatic sand and glauconite are common in amounts less than 10 percent. Some coarse sand, pebbles, and cobbles are present near its lower contact, especially in the westernmost exposures.

The Rushmere unconformably overlaps the Sunken Meadow Member over most of its extent and rests on the Eastover Formation or granite saprolite in a few locations. The Rushmere is overlain throughout most of its areal extent by the very fine silty sands of the Morgarts Beach Member. The two beds are conformable and grade into each other. The Rushmere strikes approximately northeast-southwest in Virginia and approximately north-south in North Carolina. It dips 0.5 m/km and is as much as 4.8 m thick in outcrop.

The Rushmere Member represents the maximum transgressive phase of the Yorktown Formation and occupies most of the Virginia Coastal Plain. In North Carolina, the Rushmere basin covered the Coastal Plain north and northeast of the Neuse River. The western boundary of the basin was slightly west of the Fall Line. To the north, the emerged Maryland and northern Virginia coastal plains provided a boundary. To the south, the partial barrier in the Neuse River area created a separate, though interconnected, basin that contained identical sediments called the Duplin Formation, but a warmer-water molluscan assemblage.

The Rushmere sea was clearly an open-marine, shallow-shelf environment that was conducive both to increased diversity and to large populations. The temperate molluscan assemblage reflects a subtropical influence, especially in the eastern parts of the Yorktown basin. In the more shoreward areas, diversity decreases and many of the exotic subtropical taxa are not present. South of the Neuse River barrier, the assemblage is predominantly subtropical but retains many of the taxa of the northern Yorktown basin populations. Shallow, shoaling, offshore bar systems were present in the eastern areas in Middlesex County.

The Rushmere is best exposed at Kingsmill (Locality 14) and Fort Boykin (Locality 15) but can be seen at localities 11,12 and 13. See Plate 14 for mollusks of the Rushmere Member.

Morgarts Beach Member

Maximum transgression and a high sea level stand created a quiet shelfal area in which fine sands, silts, and clays were deposited.

The Morgarts Beach Member overlies the Rushmere Member and coincides in geographic extent with that unit. This relationship is conformable and the contact is gradational. The underlying Rushmere is much more poorly sorted and contains abundant and diverse mollusks. The Morgarts Beach is distinguished by its fine, well-sorted, silty lithology and abundance of a few small bivalves, especially *Mulinia congesta,* which is sometimes exclusively present. The Morgarts Beach conforms to the same strike and dip as the underlying Rushmere and attains an outcrop thickness of 6 m. The Morgarts Beach is

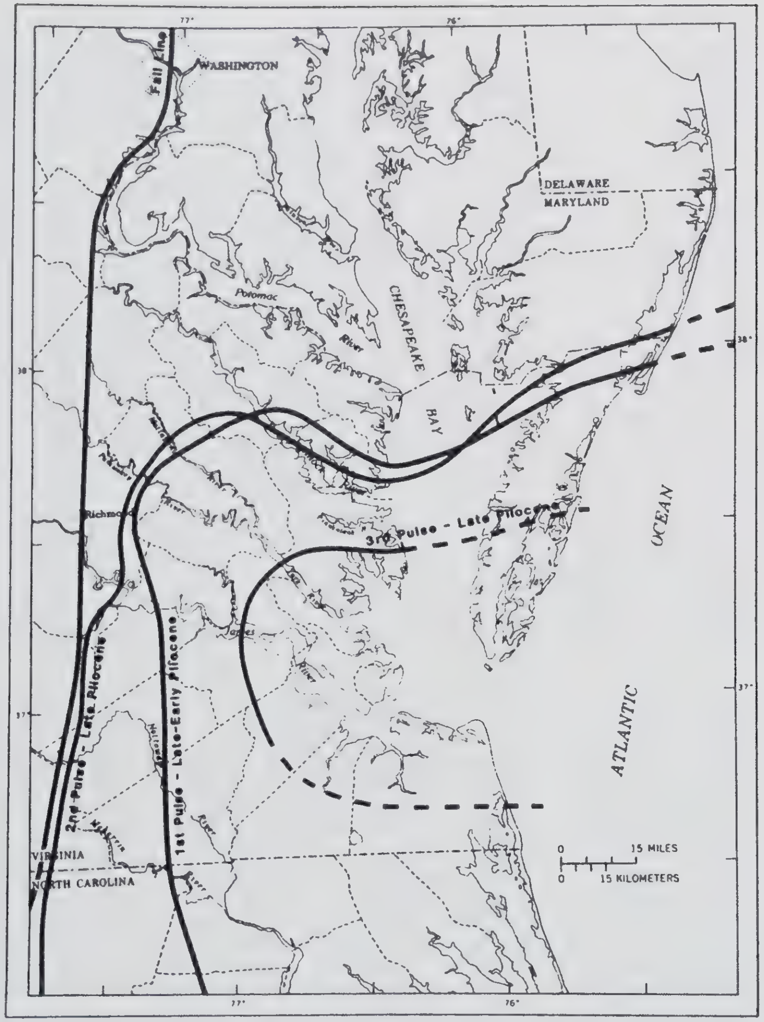


Figure 14. Areal extent of the early and late Pliocene depositional basin of the Yorktown Formation in the Salisbury Embayment. Pulse 1 resulted in the deposition of the Sunken Meadow Member, Pulse 2 resulted in the deposition of the Rushmere and Morgarts Beach Members, and Pulse 3 resulted in the deposition of the Moore House Member. Dashed lines indicate area where boundary data are lacking. Map is basedo on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).

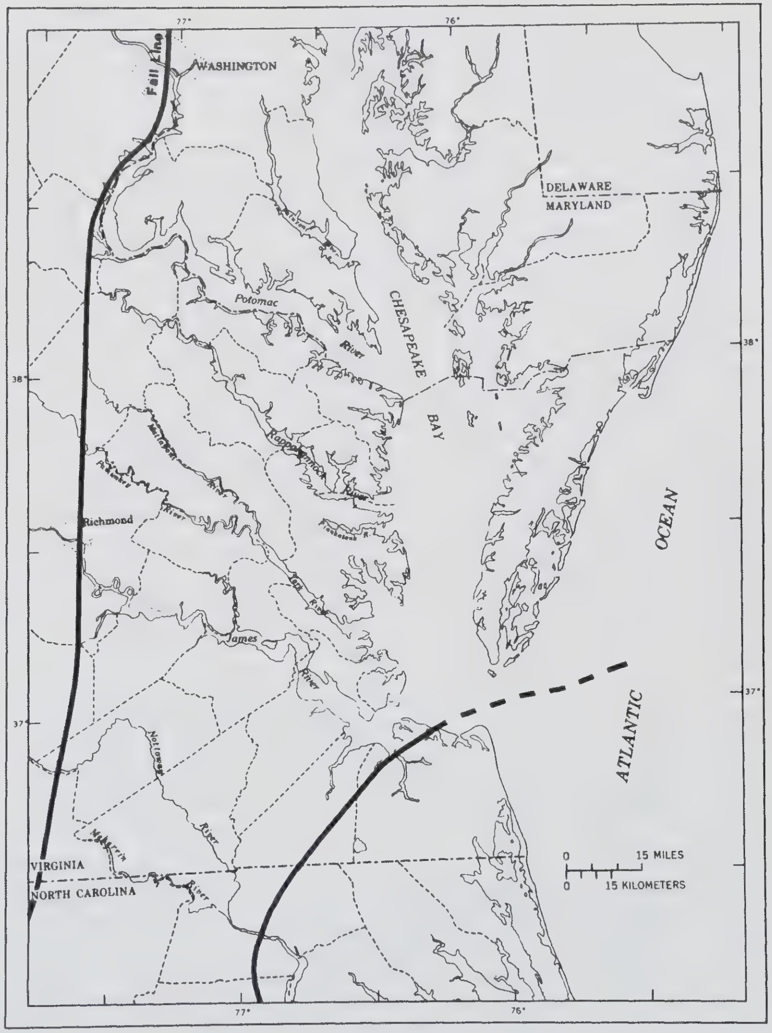


Figure 15. Areal extent of the late Pliocene depositional basin of the Chowan River Formation in the Salisbury Embayment. Dashed lines indicate area where boundary data are lacking. Map is based on outcrop and core data used in this report as well as on subsurface data from Brown *et al.* (1972).

well exposed at Fort Boykin (Locality 15). See Plate 14 for mollusks of the Morgarts Beach Member.

Moore House Member

The Moore House Member consists of sandy shell beds, cross-bedded shell hash, and bioclastic sand that is locally cemented to form a very indurated rock. It represents a separate, less extensive transgression and reflects a renewal of higher current and wave energy conditions indicative of shallower water. The Moore House Member unconformably overlies the Morgarts Beach Member in its outcrop area from Morgarts Beach to the vicinity of Rushmere on the right bank of the James River, Isle of Wight County, Virginia and at Grove Wharf, left bank of the James River, James City County, Virginia. Below Yorktown it is exposed from Cornwallis Cave to the Moore House (Locality 16) right bank of the York River, York County, Virginia. At the abandoned Lone Star Cement Quarry near Chuckatuck, Nansemond County, Virginia, the Moore House is exposed in the form of the cross-bedded shell beds of the Chuckatuck bar system. The Moore House strikes northeast-southwest and dips at approximately 5 m/km, except locally where underlying structures affect the regional dip. The maximum thickness of this member in outcrop is 6 m.

The Moore House Member is not known from North Carolina except at the Lee Creek Mine at Aurora and is mostly confined to the southeastern part of the Virginia Coastal Plain.

The Moore House Member reflects a progressively shallowing sea. Molluscan assemblages indicate normal salinities, but some of the highest beds in the Williamsburg area contain a few brackish-water mollusks. Locally, offshore, bars were the site of rapid large-scale, cross-bedded sand deposition.

The Moore House is well-exposed at the type section at the Moore House (Locality 16) and at the Deep Creek Pit (Locality 17). The Deep Creek Pit is now flooded, but was one of the rare localities where the Yorktown-Chowan River contact was exposed. See Plate 14 for mollusks of the Moore House Member.

CHOWAN RIVER FORMATION

The Chowan River Formation (Blackwelder, 1981) of late Pliocene age consists of interbedded silty fine sand, clayey silt and biofragmental sand and is subdivided into two members, the Colerain Beach and Edenhouse. Deposits of the Chowan River are extensively exposed along the Chowan River in North Carolina; however, these deposits occur locally only in the subsurface and are exposed only in borrow pits in southeastern Virginia. Because of similarity in texture and mineralogy of the Chowan River and Yorktown Formations, leaching renders them virtually indistinguishable. The formation rests unconformably on the Yorktown and is unconformably overlain by the Tabb and Shirley Formations and, locally, by the Holocene deposits. The Chowan River is sporadic in distribution, its thickness ranging from near zero east of the Suffolk scarp to more than 17 m in eastern Virginia Beach. The base of the Chowan River Formation is characterized by a discontinuous pebbly to bouldery sand that rests on the Yorktown Formation. The largest boulders have a maximum diameter of 1 m and the basal lag deposits include a diverse suite of rocks from the Appalachian Highlands. Septate siderite nodules, ferricrete clasts, iron oxide-cemented burrows and phosphate pebbles, which were eroded from the Yorktown Formation, are also present.

The basal lag deposits of the Chowan River Formation grade upward into fine to medium sand, interbedded silty sand, clayey silt and biofragmental sand. The clayey silt and silty sand contain bivalve ghosts and burrows. The biofragmental sand is cross-bedded and contains a diverse, warm, shallow-water fauna including *Carolinapecten eboreus, Costaglycymeris hummi, Ostrea raveneliana, Noetia carolinensis, Rangia, Corbicula,* and *Mercenaria.* See Plate 15 for mollusks of the Chowan River Formation.

The Chowan River has been exposed at the Deep Creek Pit (Locality 17) and in other borrow pits around Hampton and Norfolk.

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PLATES

PLATE 1

Plants from the Patuxent Formation Common at Dutch Gap (from Fontaine 1889)

- Figures 1, 5, 6. *Sphenolepidium Kurrianum* Heer
    - 1. Portion of a copiously branched twig
    - 1a. Portion of 1 magnified
    - 5. Portions of several detached branches
    - 5a. Portion of 5 magnified
    - 6. Portion of a copiously branched twig
    - 6a. Portion of 6 magnified
- Figure 2. *Sequoia rigida* Heer
    - 2. Fragment of a copiously branched twig
    - 2a. Leaves magnified
- Figures 3, 4. *Sequoia gracilis* Heer
    - 3. Portion of a small twig
    - 3a. Leaves magnified
    - 4. Fragment of a copiously branching twig

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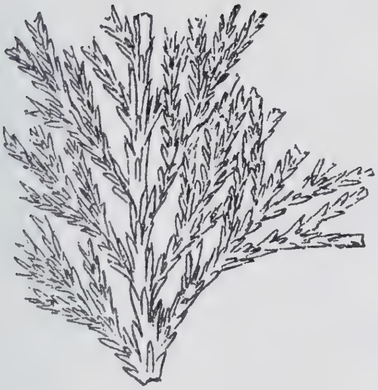

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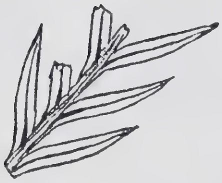

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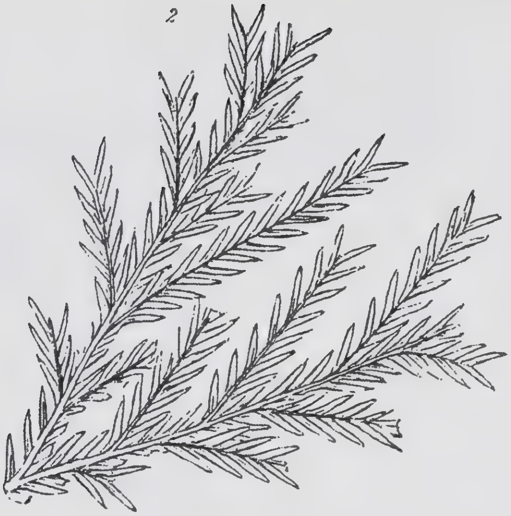

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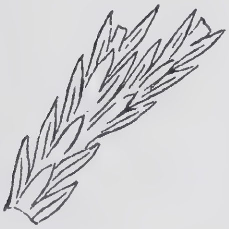

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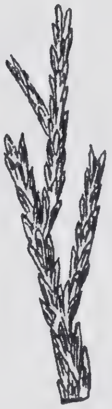

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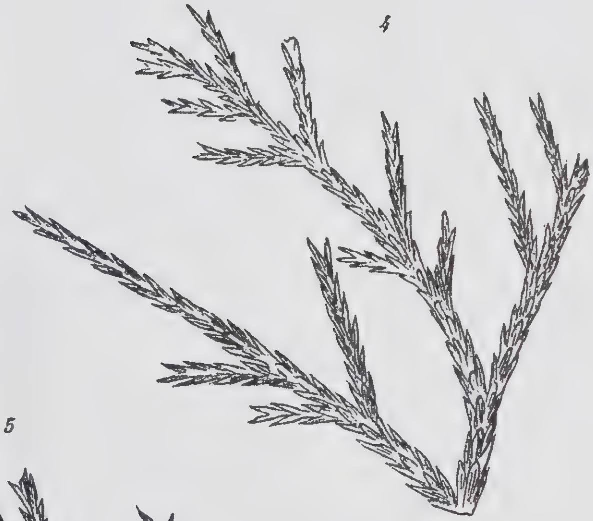

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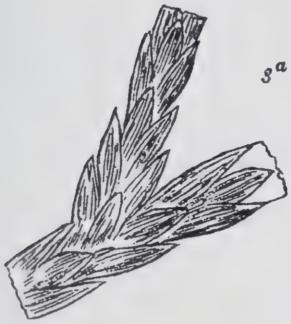

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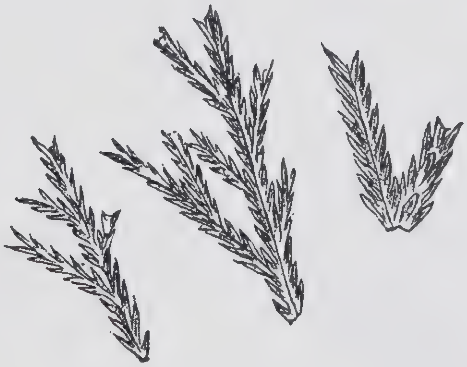

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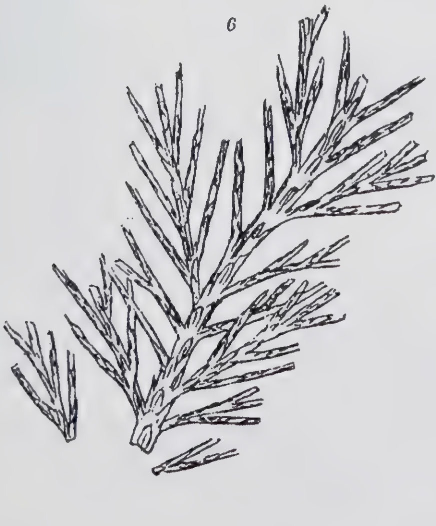

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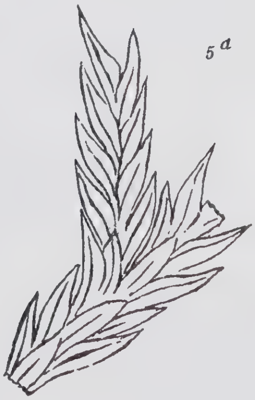

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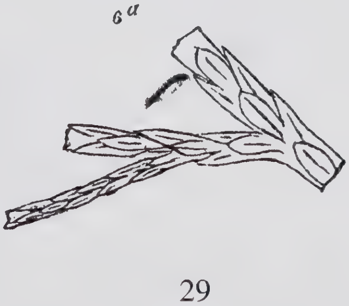

PLATE 2

Plants from the Patuxent Formation Common at Dutch Gap
(from Fontaine, 1889)

- Figures 1-5. *Aspidium heterophyllum*, sp. nov.
  - 1. Portion of a fructified ultimate pinna
  - 1a. Magnified pinnule of 1, to show sori and nerves
  - 2. Portion of the upper part of a primary pinna or of the frond
  - 3. Portion of a secondary pinna
  - 3a. Pinnules of 3 magnified
  - 4. Portion of a secondary pinna from low down on the plant
  - 4a. Magnified pinnules of 4
  - 5. Portion of a fructified secondary pinna
  - 5a. Pinnules of 5 magnified, to show sori and nervation
- Figure 6. *Cladophlebis*, species undetermined
  - 6. Small fragment of a pinna from bank near Brooke
  - 6a. Pinnule of 6 magnified
- Figure 7. *Aspidium Virginicum*, sp. nov
  - 7. Small fragment of an ultimate pinna
  - 7a. Magnified pinnule of 7
- Figure 8. *Pecopteris ovatodentata*, sp. nov.
  - 8. Portion of an ultimate pinna
  - 8a. Pinnule of 8 magnified

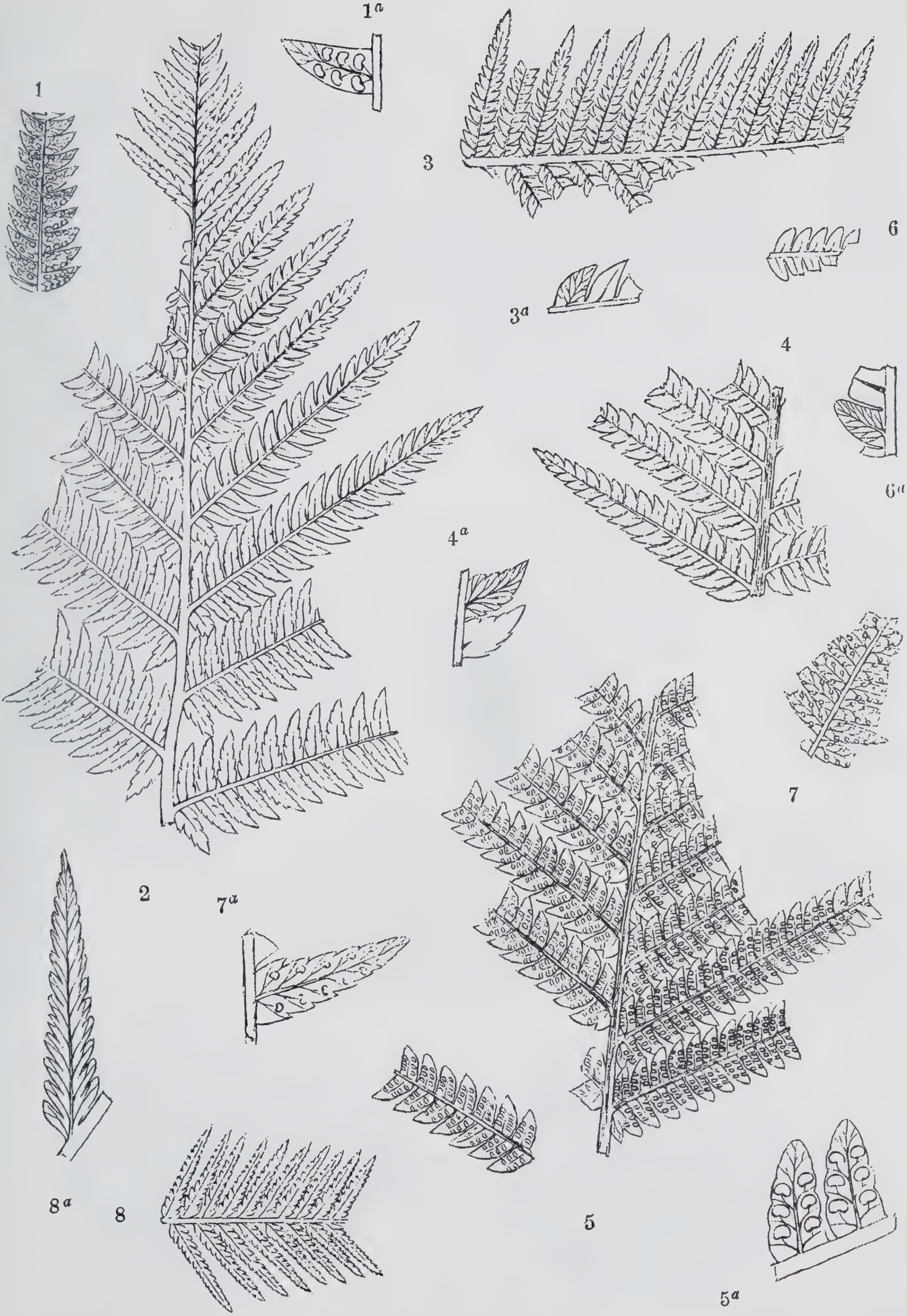
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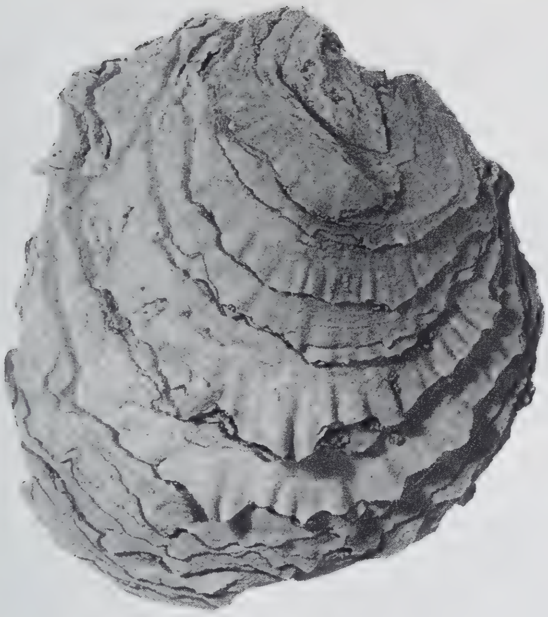
PLATE 3. Mollusks Common in the Piscataway Member of the Aquia Formation.

All specimens were collected from the Pamunkey River, 0.5 mile (0.8 km) east of Wickham Crossing, Hanover County, Virginia (Locality 8) (USGS Locality 26337)

Figures 1, 2, 4, 5. *Ostrea alepidota* Dall, 1898.
  1. Left valve of specimen (USNM 366470; length 73.5 mm, height 85.1 mm)
  2. Right valve of specimen (USNM 366470; length 65.4 mm, height 82.6 mm)
  4. Left valve of specimen (USNM 366472); length 58.9 mm, height 74.3 mm.
  5. Left valve of specimen (USNM 366473); length 36.3 mm, height 44.6 mm.

3. *Turritella humerosa* Conrad, 1835.
  Apertural view of an incomplete specimen (USNM 366471); height 32.5 mm.
6. *Turritella mortoni* Conrad, 1830.
  Apertural view of an incomplete specimen (USNM 366474); height 35.8 mm.
7. *Cucullaea gigantea* Conrad, 1830.
  Left valve of specimen (USNM 366475); length 42.4 mm, height 27.4 mm.
8. *Pitar pyga* Conrad, 1845.
  Left valve of a double-valved specimen (USNM 366476); length 46.3 mm, height 38.9 mm.
9. *Crassatellites capricranium* (Rogers, 1839).
  Left valve of specimen (USNM 366477); length 59.1 mm. height 38.6 mm.
10. *Dosiniopsis lenticularis* (Rogers, 1839).
  Left valve of specimen (USNM 366478); length 47.1 mm, height 44.5 mm.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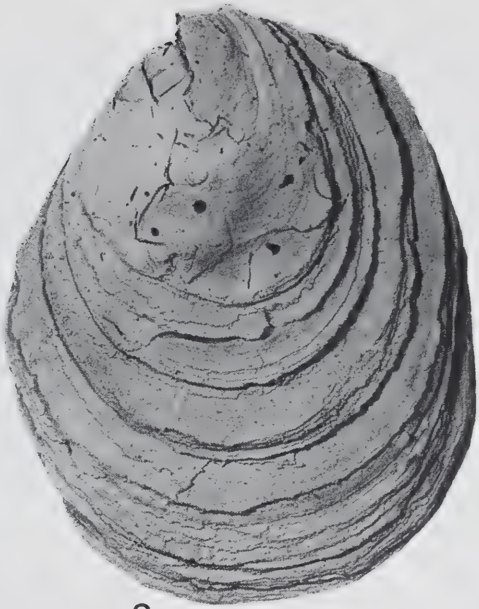
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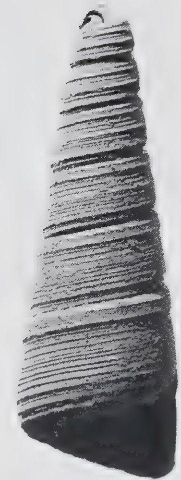
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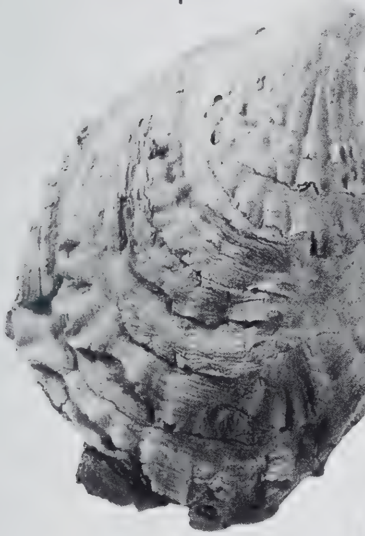
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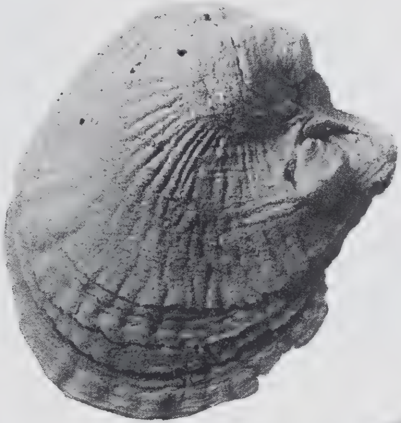
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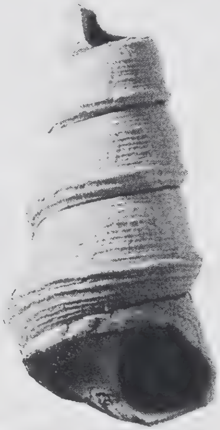
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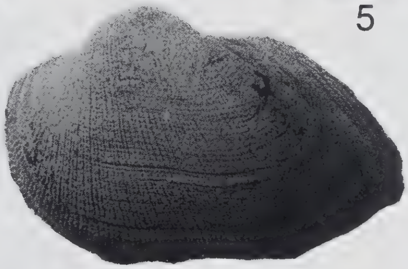
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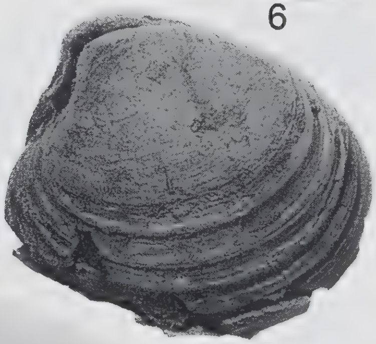
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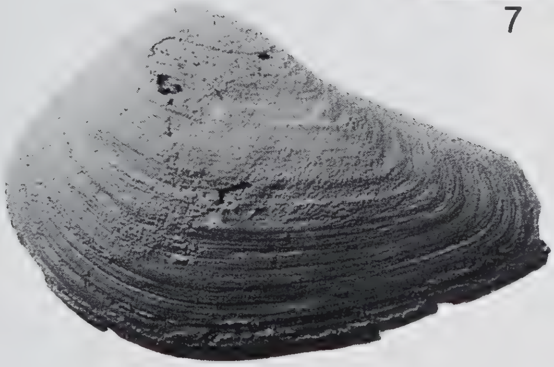
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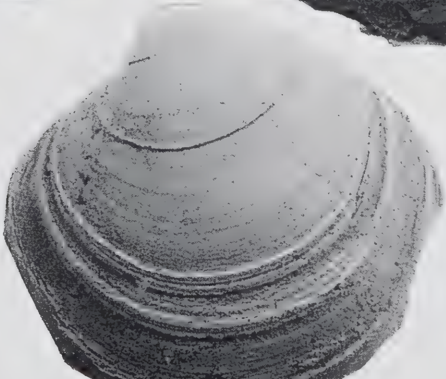
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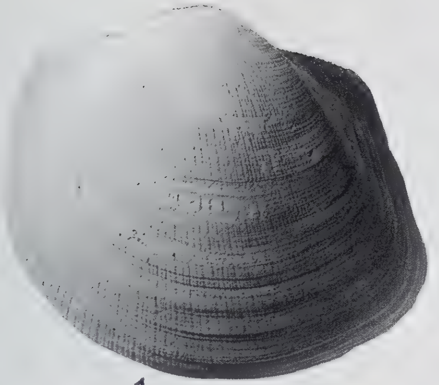
PLATE 4. Mollusks Common in the Paspotansa Member of the Aquia Formation.

All except Figure 5 were collected from the Potomac River, 0.3 mile (0.5 km) above Belvedere Beach, King George County, Virginia (Locality 30)

Figure 1. *Cucullaea gigantea* Conrad, 1830.
  Left valve of specimen (USNM 366479); length 83.3 mm, height 71.8 mm.
2. *Pycnodonte* sp.
  Left valve of specimen (USNM 366480); length 74.2 m., height 74.6 mm.
3. *Turritella mortoni* Conrad, 1830.
  Apertural view of specimen (USNM 366481); height 105.0 mm.
4, 8. *Ostrea sinuosa* Rogers and Rogers, 1837.
  4. Left valve of specimen (USNM 366482; length 152.8 mm. height 134.3 mm.
  8. Right valve of specimen (USNM 366482; length 98.8 mm, height 118.3 mm.
5. *Venericardia regia* Conrad, 1865.
  Left valve of specimen (USNM 366483) from the Potomac River 0.1 mile (0.3 km) below the mouth of Passapatanzy Creek, King George County, Virginia (Locality 12) (USGS Locality 26341); length 75.4 mm, height 71.7 mm.
6. *Turritella mortoni* Conad, 1830.
  Apertural view of nearly complete specimen (USNM 366484); height 92.3 mm.
7. *Crassatellites alaeformis* Conrad, 1830.
  Right valve of specimen (USNM 366485); length 51.9 mm, height 22.7 mm.
9. *Pitar pyga* Conrad, 1845.
  Right valve of specimen (USNM 366486); length 33.6 mm, height 28.1 mm.
10. *Turritella humerosa* Conrad, 1835.
  Apertural view of an incomplete specimen (USNM 366487); height 49.8 mm.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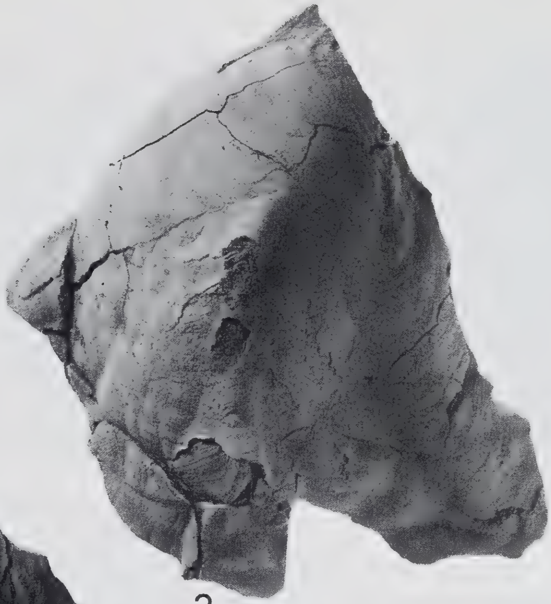
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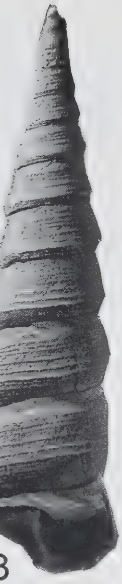
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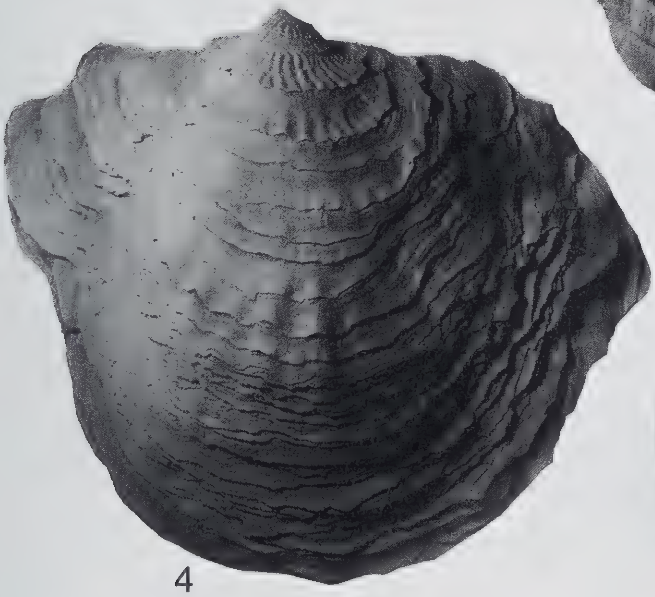
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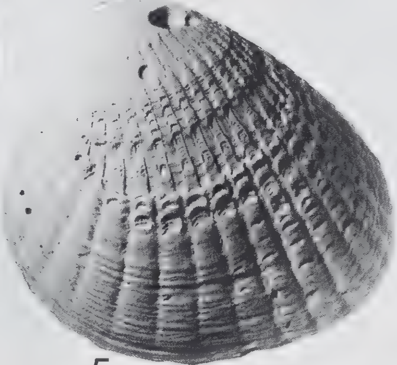
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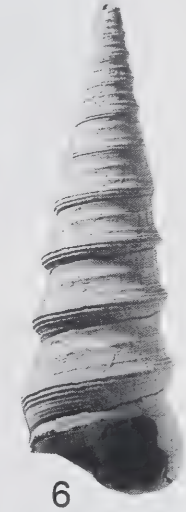
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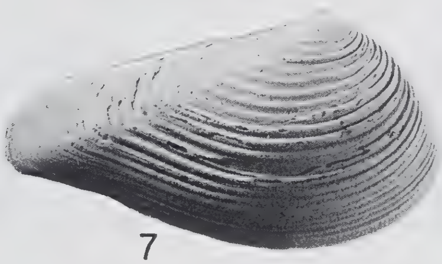
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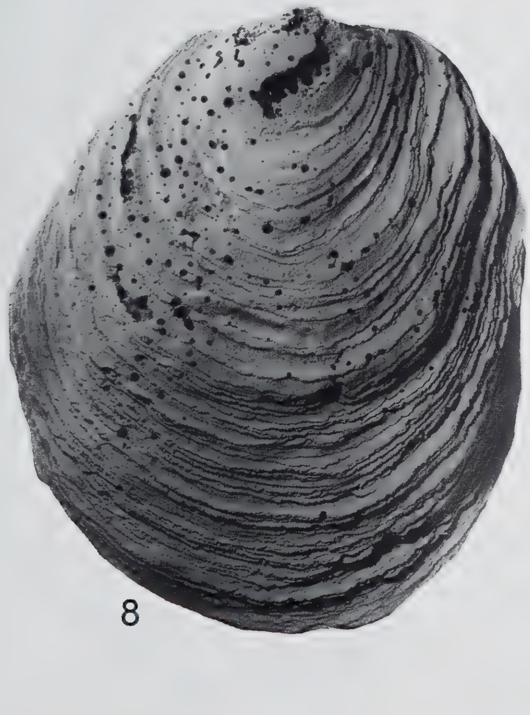
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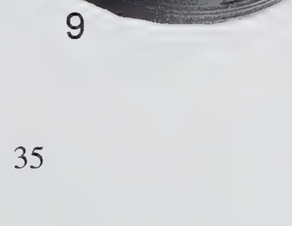
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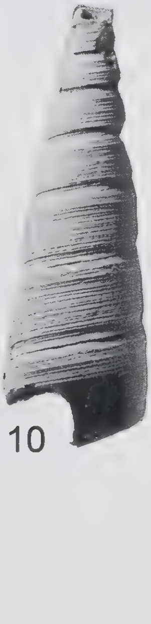
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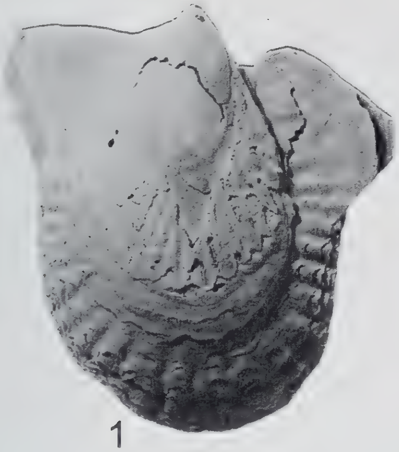
PLATE 5. Mollusks Common in the Potapaco Member of the Nanjemoy Formation.

Figures 1, 3, and 5 from the Pamunkey River, 0.8 mile (1.3 km) below Hanovertown, Hanover County, Virginia (Locality 48) (USGS Locality 26377). Figures 2, 4, and 6 from the Pamunkey River, 0.45 mile (0.72 km) above the mouth of Millpond Creek on the right bank. Hanover County, Virginia (USGS Locality 26424). Figures 7-9, 11, and 12 from the Potomac River, 2.3 miles (3.9 km) above Popes Creek, Charles County, Maryland (USGS Locality 26425). Figure 10 from the Rappahannock River, opposite Goat Island, Caroline County, Virginia (Locality 31) (USGS Locality 26360).

Figure
1. *Cubitostrea sp.*
   Left valve of specimen (USNM 366488); length 48.5 mm, height 51.6 mm.
2. *Cubitostrea* sp.
   Left valve of specimen (USNM 366489); length 35.7 mm, height 50.4 mm.
3. *Cubitostrea* sp.
   Left valve of specimen (USNM 366490); length 37.7 mm, height 58.5 mm.
4. *Cubitostrea* sp.
   Left valve of specimen (USNM 366491); length 18.7 mm, height 27.6 mm.
5. *Cubitostrea* sp.
   Right valve of specimen (USNM 366492); length 47.9 mm, height 56.2 mm.
6. *Cubitostrea* sp.
   Right valve of specimen (USNM 366493); length 18.8 mm, height 21.4 mm
7. *Venericardia potapacoensis* Clark and Martin, 1901.
   Left valve of specimen (USNM 366494; length 29.0 mm, height 24.1 mm.
8. *Nuculana parva* (Rogers, 1837).
   Right valve of specimen (USNM 366495); length 4.62 mm, height 2.85 mm.
9. *Vokesula* sp.
   Right valve of specimen (USNM 366496); length 4.48 mm, height 4.20 mm.
10. *Lucina* sp.
    Right valve of specimen (USNM 366497); length 5.14 mm, height 4.66 mm.
11. *Vokesula* sp.
    Right valve of specimen (USNM 366498); length 4.29 mm, height 3.65 mm.
12. *Cadulus* sp.
    Lateral view of incomplete specimen (USNM 366499); length 3.45 mm.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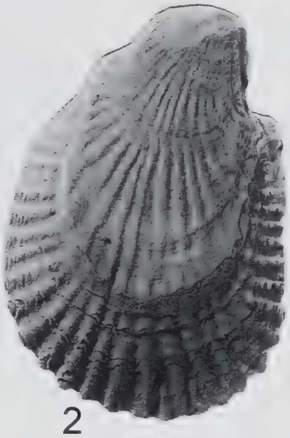
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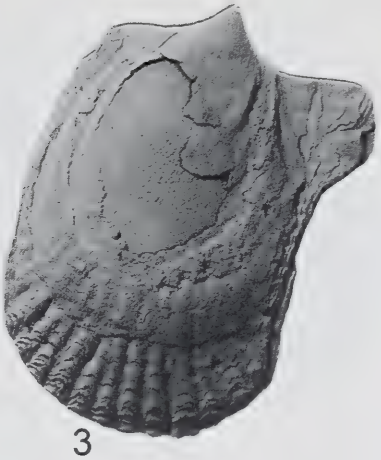
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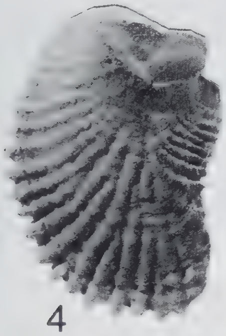
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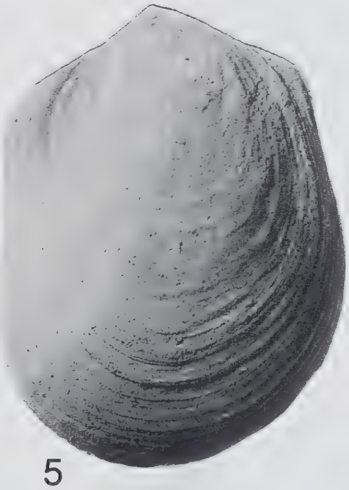
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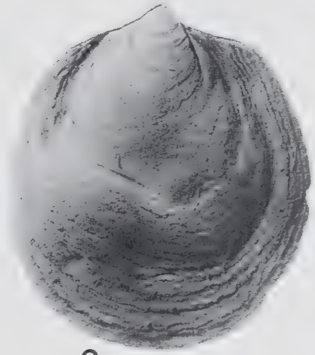
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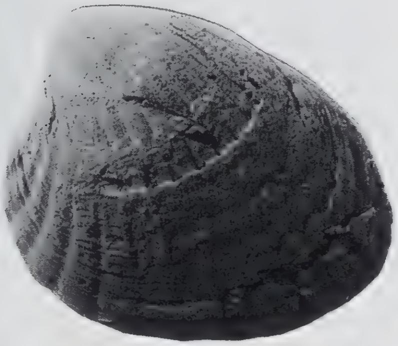
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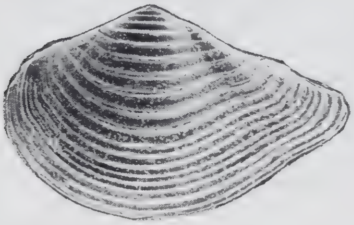
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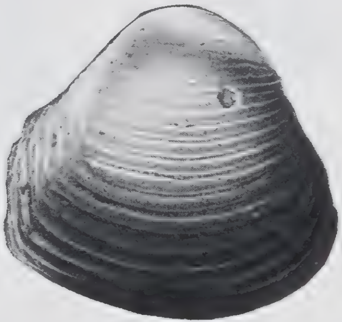
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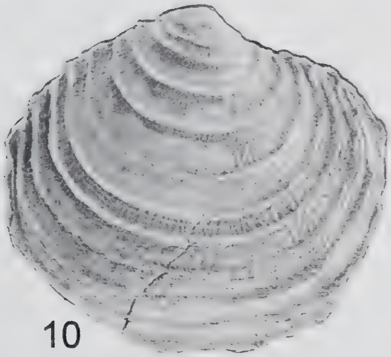
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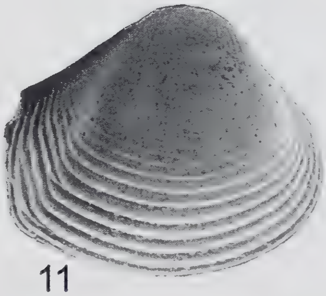
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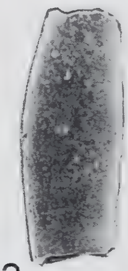
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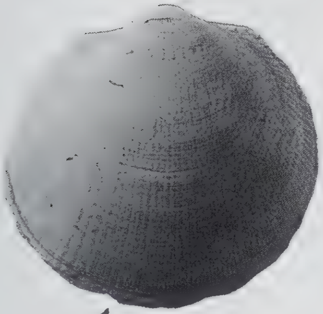
PLATE 6. Mollusks Common in the Woodstock Member of the Nanjemoy Formation.

Figures 5, 6, and 10-14 from the Pamunkey River, in a small ravine, 0.63 mile (1.01 km) south-southeast of the mouth of Totopotomoy Creek, Hanover County, Virginia (Locality 74) (USGS Locality 26403). Other localities are as described below.

Figure 1. *Glycymeris* sp.
  Right valve of specimen (USNM 366500) from the Pamunkey River at the termination of Route 732, Hanover County, Virginia (Locality 64) (USGS Locality 26393); length 22.0 mm, height 21.0 mm.
2-4 Specimens from the Potomac River, 0.95 miles (1.53 km) below the mouth of Popes Creek, Charles County, Maryland (Locality 68) (USGS Locality 26397).
  2. *Cubitostrea* sp.
    Left valve of specimen (USNM 366501); length 13.8 mm, height 20.2 mm.
  3. *Cubitostrea* sp.
    Left valve of specimen (USNM 366502); length 11.8 mm, height 17.0 mm
  4. *Cubitostrea* sp.
    Right valve of specimen (USNM 366503); length 12.0 mm, height 22.0 mm.
5. *Nuculana* sp.
  Right valve of specimen (USNM 366504); length 4.14 mm, height 2.56 mm.
6. *Macrocallista subimpressa* (Conrad, 1848).
  Left valve of specimen (USNM 366505); length 21.3 mm, height 13.9 mm.
7-9. Specimens from the Pamunkey River, just upstream of the old Newcastle Bridge, Hanover County Virginia (Locality 76) (USGS Locality 26405).
  7. *Corbula aldrichi* Meyer, 1885.
    Right valve of specimen (USNM 366506); length 10.0 mm, height 7.5 mm.
  8. *Venericardia ascia* Rogers and Rogers, 1839.
    Right valve of specimen (USNM 366507); length 41.4 mm, height 37.5 mm.
  9. *Venericardia ascia* Rogers and Rogers, 1839.
    Right valve of specimen (USNM 366508); length 62.6 mm, height 54.1 mm.
10. *Lucina dartoni* Clark, 1895.
  Left valve of specimen (USNM 366509); length 6.1 mm, height 5.2 mm.
11. *Lunatia* sp.
  Apertural view of specimen (USNM 366510); height 14.2 mm.
12. *Turritella* sp.
  Apertural view of incomplete specimen (USNM 366511); height 12.2 mm.
13. *Turritella* sp.
  Apertural view of incomplete specimen (USNM 366512); height 14.4 mm.
14. *Cadulus* sp.
  Lateral view of nearly complete specimen (USNM 366513); height 4.93 mm.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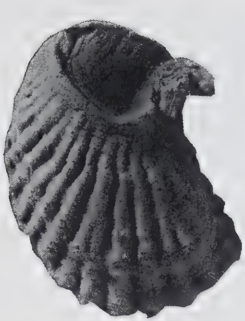
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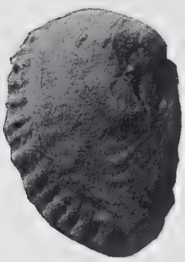
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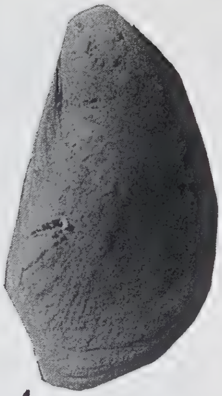
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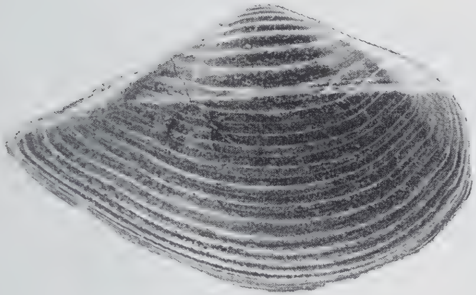
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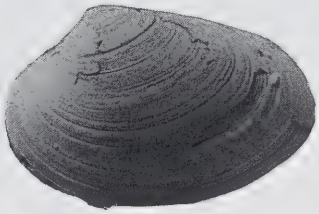
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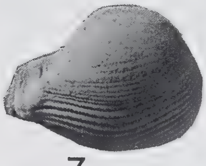
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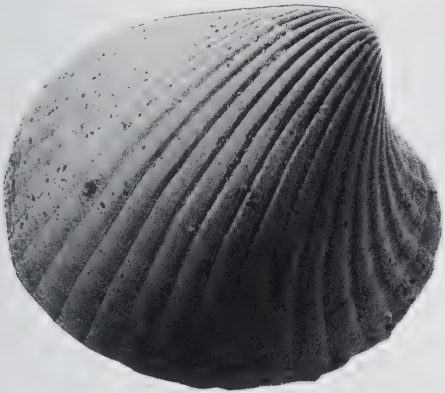
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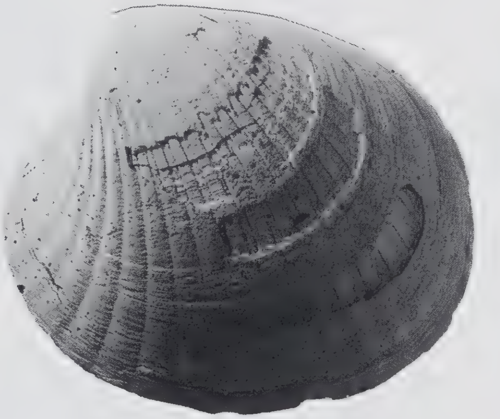
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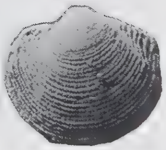
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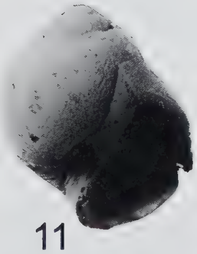
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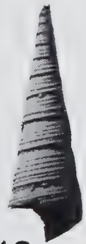
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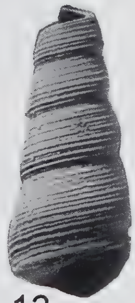
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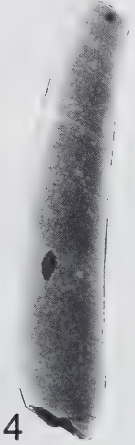
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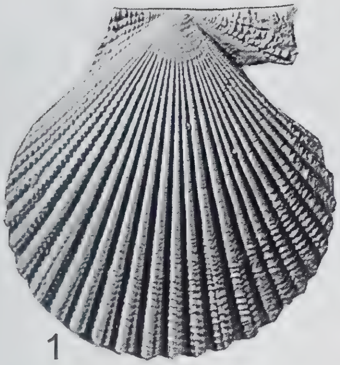
PLATE 7. Mollusks Common in the Piney Point Formation

Figures 1-3, 8-19, and 21 from the Pamunkey River, 1.0 miles (1.6 km) west of Horseshoe, Hanover County, Virginia (Locality 37) USGS Locality 26427). Figures 4 and 20 from the Pamunkey River at the termination of Route 732, Hanover County, Virginia (Locality 36) (USGS Locality 26426). Figures 5-7 from the Pamunkey River at Horseshoe, Hanover County, Virginia (Locality 40) (USGS Locality 26412).

Figure 1. *"Pecten"* sp.
  Right valve of specimen (USNM 366514); length 15.0 mm, height 15.8 mm.
2. *"Pecten"* sp.
  Right valve of specimen (USNM 366515); length 7.1 mm, height 7.6 mm.
3. *"Pecten"* sp.
  Right valve of specimen (USNM 366516); length 11.7 mm, height 12.4 mm.
4-6, 8, 9. *Cubitostrea sellaeformis* (Conrad, 1832)
  4. Left valve of a double-valved individual (USNM 366517); length 110.9 mm, height 99.7 mm.
  5. Left valve of specimen (USNM 3666518); length 77.7 mm, height 76.3 mm.
  6. Right valve of specimen (USNM 366519); length 70.7 mm, height 82.3 mm.
  8. Left valve of specimen (USNM 366521); length 16.1 mm, height 24.2 mm.
  9. Left valve of specimen (USNM 366522); length 11.1 mm, height 19.7 mm.
7. *Plicatula filamentosa* Conrad, 1833
  Right valve of incomplete specimen (USNM 366520); length 10.5 mm, height 9.2 mm.
10. *Anomia lisbonensis* (Aldrich, 1886)
  Left valve of specimen (USNM 366523); length 17.5 mm, height 19.4 mm.
11. *Leda coelatella* Van Winkle, 1919
  Left valve of specimen (USNM 366524); length 15.3 mm, height 6.8 mm.
12. *Leda semen* Lea, 1833
  Right valve of specimen (USNM 366525); length 11.2 mm, height 5.8 mm.
13. *Glycymeris lisbonensis* Harris, 1919
  Right valve of specimen (USMN 366526); length 18.5 mm, height 16.9 mm.
14-16. *Anapteris regalis* Van Winkle, 1919
  14. Left valve of specimen (USNM 366527); length 15.5 mm, height 8.5 mm.
  15. Left valve of specimen (USNM 366528); length 14.5 mm, height 7.6 mm.
  16. Left valve of specimen (USNM 366529); length 14.5 mm, height 14.0 mm.
17. *Turritella nasuta* Gabb, 1860
  Apertural view of incomplete specimen (USNM 366530); height 11.1 mm.
18. *Dentalium* sp.
  Lateral view of specimen (USNM 366531); height 11.4 mm.
19. *Dentalium* sp.
  Lateral view of specimen (USNM 366532); height 9.2 mm.
20. *Corbula* sp.
  Right valve of specimen (USNM 366533); length 8.7 mm, height 5.5 mm.
21. *Caestocorbula fossata* (Meyer and Aldrich, 1886)
  Right valve of specimen (USNM 366534); length 6.9 mm, height 4.6 mm.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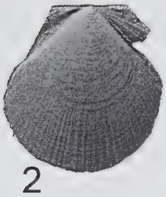
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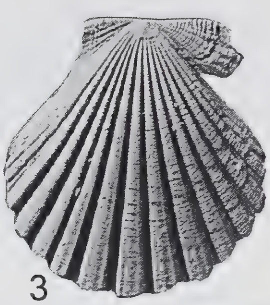
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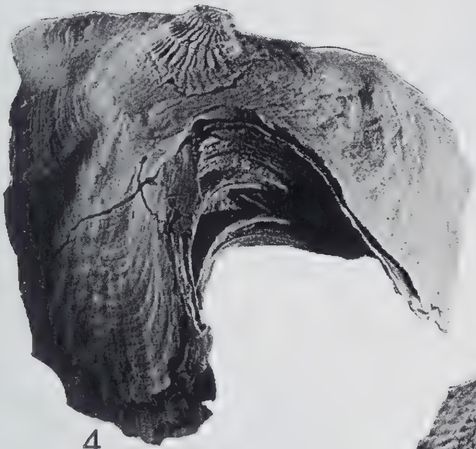
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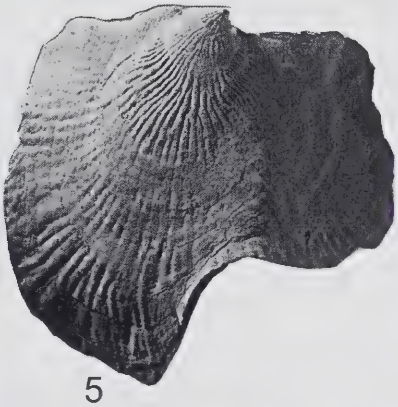
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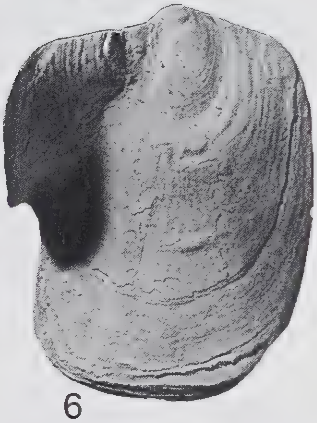
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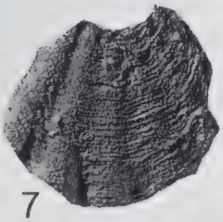
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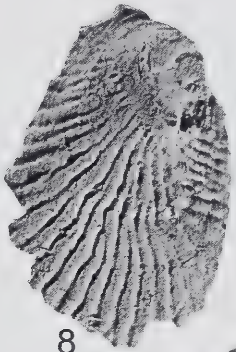
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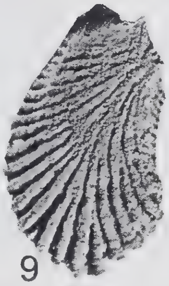
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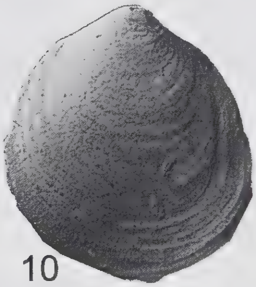
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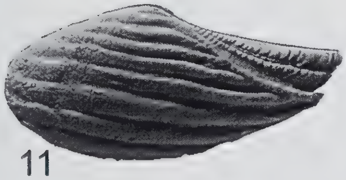
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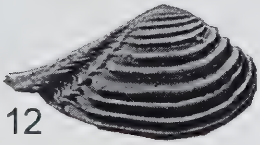
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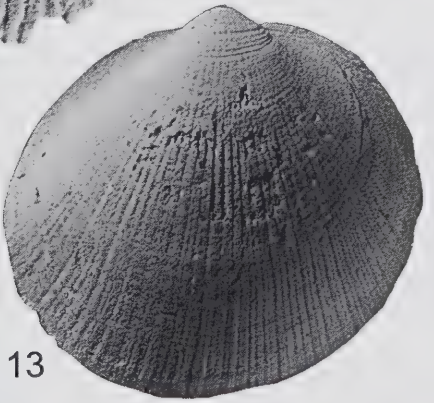
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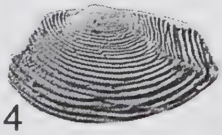
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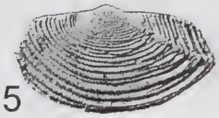
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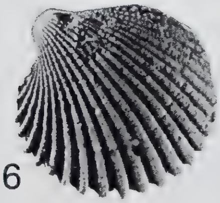
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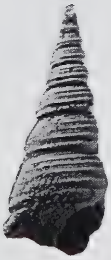
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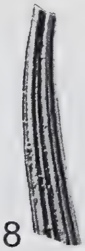
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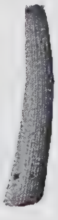
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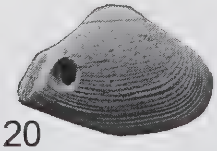
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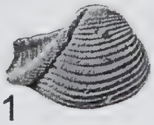
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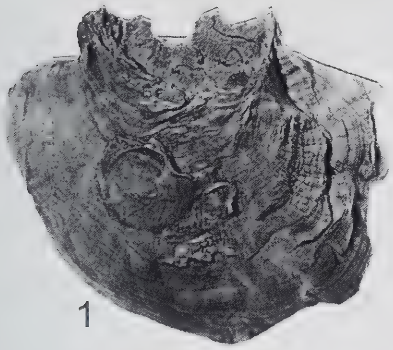
PLATE 8. Mollusks Common in the Old Church Formation

All specimens from the Warren Brothers sand pit, 1.4 miles (2.3 km) southeast of Bottoms Bridge, Henrico County, Virginia (Locality 64) (USGS Locality 26417).

Figure 1. *Pycnodonte* sp.
 Left valve of specimen (USNM 366535); length 80.9 mm, height 66.7 mm.
2. *Pycnodonte* sp.
 Left valve of specimen (USNM 366536); length 53.9 mm, height 57.0 mm.
3. Py*cnodonte* sp.
 Right valve of specimen (USNM 366535); length 60.2 mm, height 59.2 mm.
4. *Anomia ruffini* Conrad, 1843
 Left valve of specimen (USNM 366537); length 49.5 mm, height 47.7 mm.
5. *Pecten* sp.
 Right valve of specimen (USNM 366538); length 11.5 mm, height 12.3 mm.
6. *Pecten* seabeensis Richards, 1947
 Right valve of specimen (USNM 366539); length 11.3 mm, height 11.5 mm.
7. *Bicorbula idonea* (Conrad, 1833)
 Latex cast of right valve (USNM 366540); length 23.9 mm, height 18.7 mm.
8. *Mercenaria gardnerae* Kellum, 1926
 Latex cast of right valve (USNM 366541); length 44.5 mm, height 38.4 mm.
9. *Lucina* sp.
 Internal mold of left valve (USNM 366542); length 30.7 mm, height 25.7 mm.
10. *Lucina* sp.
 Latex cast of hinge area of double-valved individual (USNM 366543); length 36.4 mm.
11. *Hippochaeta* sp.
 Partial external mold of right valve (USNM 366544) preserved as a xenomorphic structure on a *Pycnodonte* sp.; length 87.4 mm, height 56.0 mm.
12. *Ecphora* sp.
 Latex cast of incomplete specimen (USNM 366545); height 16.6 mm.
13. *Panopea* sp.
 Internal mold of left valve of specimen (USNM 366546); length 45.6 mm, height 30.1 mm.
14. *Plicatula* sp.
 Exterior view of a fragment (USNM 366547); length 11.6 mm. height 11.2 mm.
15. *Plicatula* sp.
 Exterior view of fragment (USNM 366548); length 16.0 mm, height 15.1 mm.
16. *Cyclocardia* sp.
 Latex cast of right valve of specimen (USNM 366549); length 15.3 mm, height 15.9 mm.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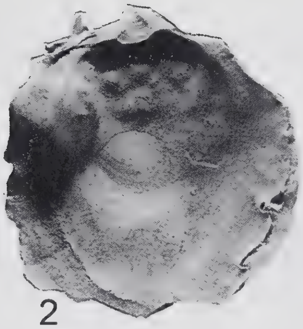
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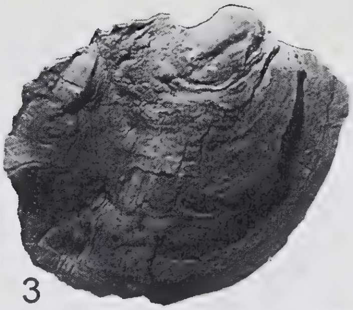
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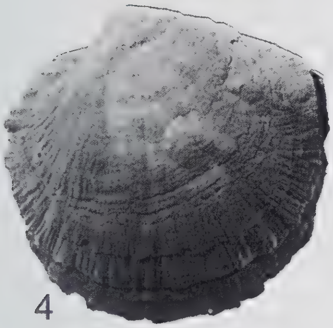
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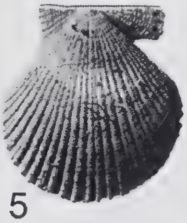
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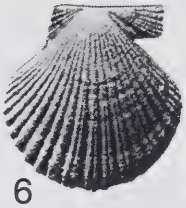
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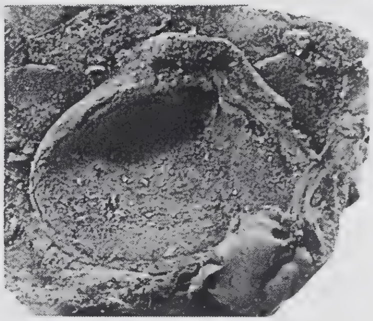
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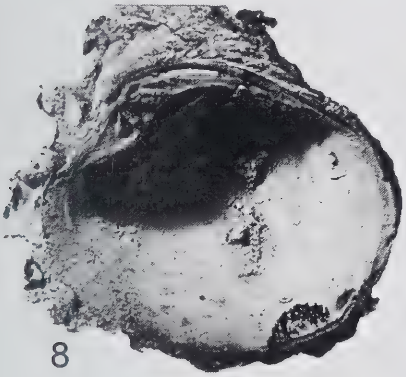
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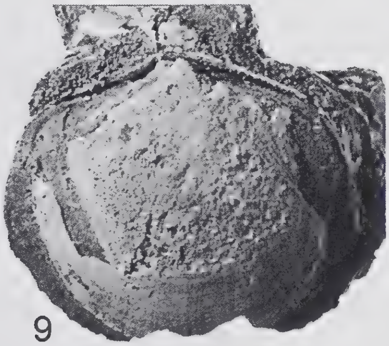
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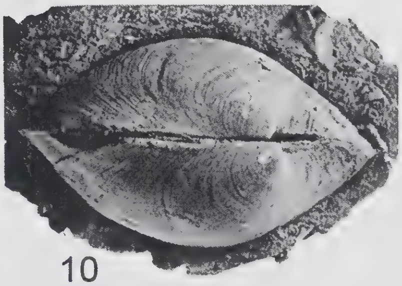
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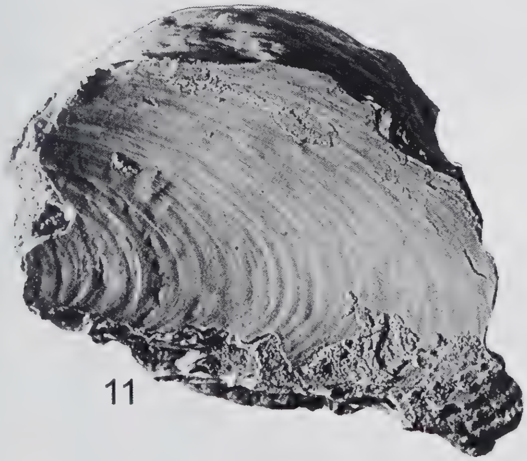
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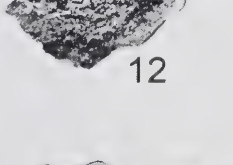
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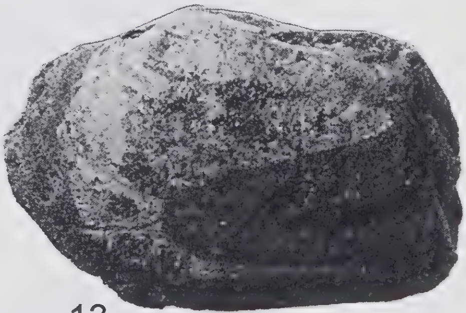
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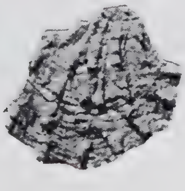
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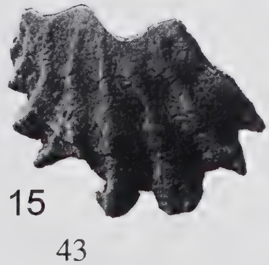
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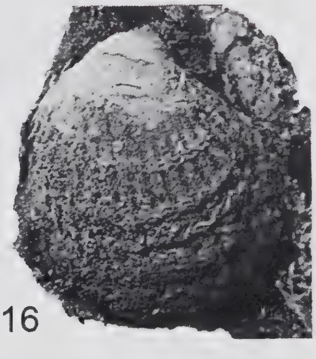
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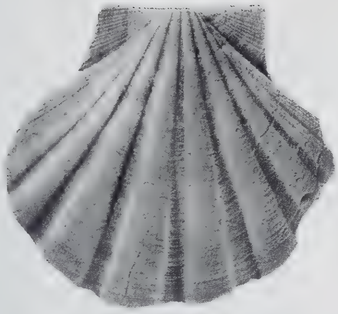
PLATE 9. Mollusks Common in the Calvert Formation

Figure

1. *Pecten humphreysii* Conrad, 1842
   Right valve of a specimen (USNM 380693) from Plum Point, on the Chesapeake Bay, Calvert County, Maryland; length 52.2 mm, height 47.6 mm.
2. *Bicorbula idonea* (Conrad, 1833)
   Right valve of a specimen (USNM 380694) from Camp Roosevelt, on the Chesapeake Bay, Calvert County, Maryland; length 28.0 mm, height 24.9 mm.
3. *Pecten humphreysii* Conrad, 1842
   Left valve of a specimen (USNM 380695) from Plum Point, on the Chesapeake Bay, Calvert County, Maryland; length 48.4 mm, height 35.5 mm.
4. *Lirophora latilirata* (Conrad, 1841)
   Right valve of a specimen (USNM 380696) from Plum Point, on the Chesapeake Bay, Calvert County, Maryland; length 19.9 mm., height 15.6 mm.
5. *Melosia staminea* (Conrad, 1839)
   Right valve of a specimen (USNM 3280697) from Camp Roosevelt, on the Chesapeake Bay, Calvert County, Maryland; length 30.0 mm., height 28.0 mm.
6. *Astarte cuneiformis* Conrad, 1840
   Left valve of a specimen (USNM 380698) from Camp Roosevelt, on the Chesapeake Bay, Calvert County, Maryland, length 35.6 mm, height 25.0 mm.
7. *Mercenaria blakei* Ward, 1992
   Right valve of a specimen (USNM 380699) from Mrs. Anderson's Cottages, near Plum Point, on the Chesapeake Bay, Calvert County, Maryland; length 92.5 mm, height 91.4 mm.
8. *Marvacrassatella melinus* (Conrad, 1832)
   Left valve of a specimen (USNM 380700) from Camp Roosevelt, on the Chesapeake Bay, Calvert County, Maryland; length 80.9 mm, height 51.8 mm.
9. *Ecphora tricostrata* Martin, 1904
   Apertural view of a specimen (USNM 380701) from Plum Point, on the Chesapeake Bay, Calvert County, Maryland; height 73.6 mm.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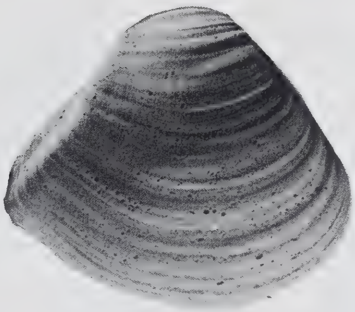
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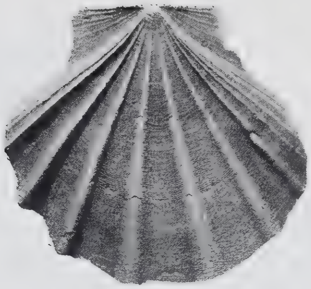
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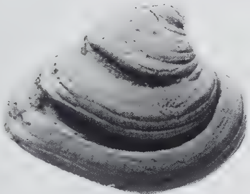
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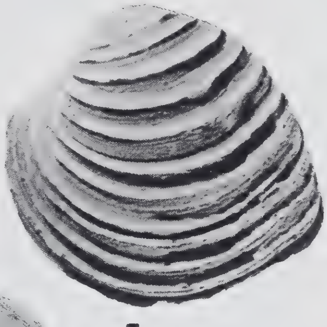
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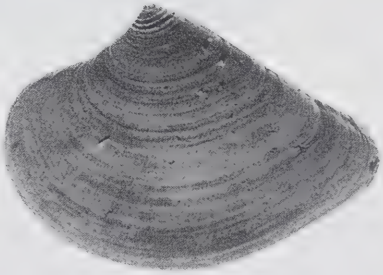
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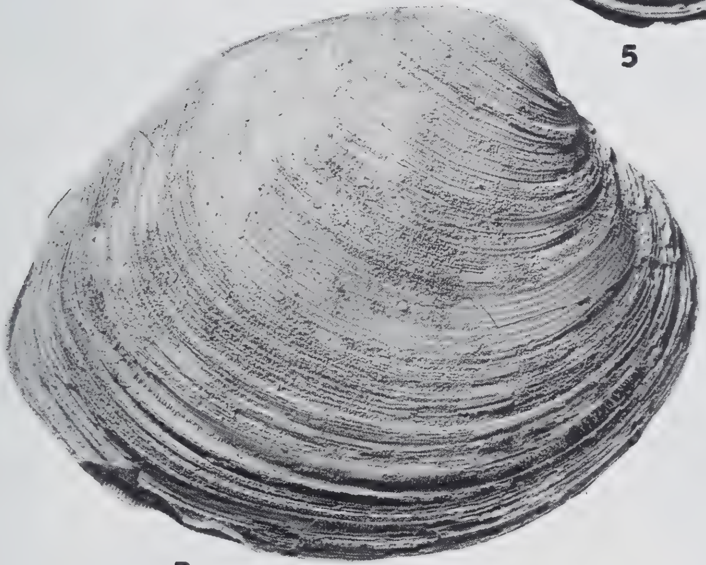
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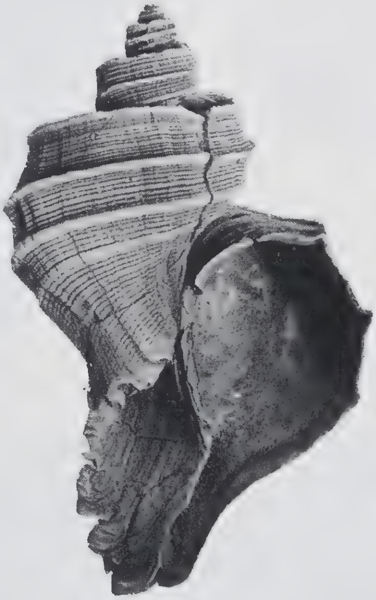
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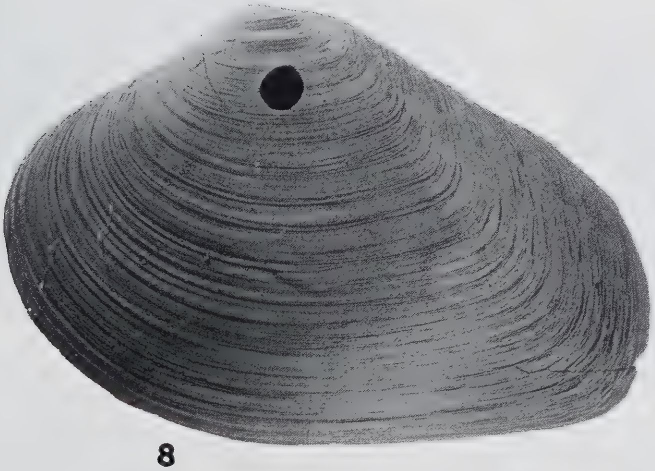
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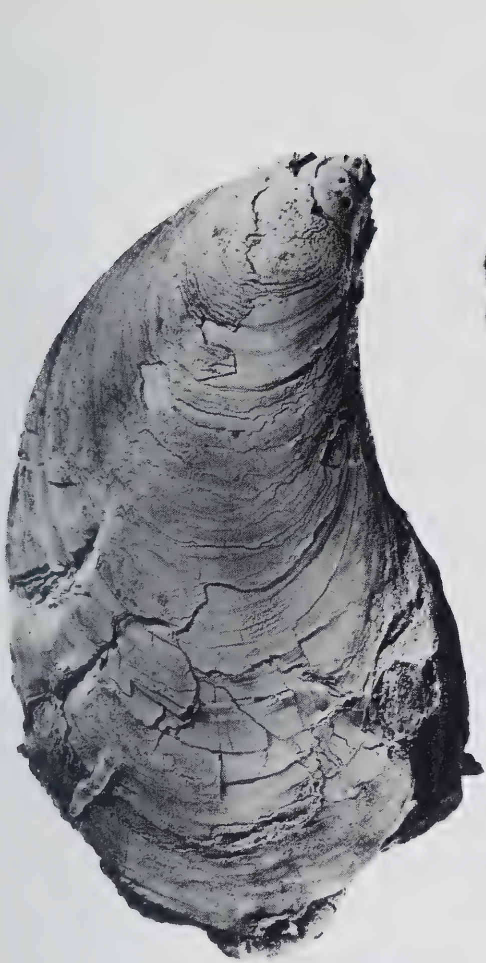
PLATE 10. Mollusks Common in the Claremont Manor Member of the Eastover Formation

Figures 1, 4, and 6 from Cobham Wharf, Virginia (USGS Locality 26052). Figures 2, 3, 5, 10, and 12 from just above Sunken Meadow Creek, Surry County, Virginia (USGS Locality 26041). Figures 7-9 and 11 from just below the mouth of Upper Chippokes Creek on the James River, Surry County, Virginia (USGS Locality 26042).

Figure 1. *Hippochaeta* sp.
Right valve of a nearly complete specimen (USNM 258347); length 150.3 mm.
2. *Ecphora whiteoakensis* Ward and Gilinsky, 1988
Apertural view of specimen (USNM 258348); height 74.4 mm.
3. *Mercenaria* druidi Ward, 1992
Left valve of specimen (USNM 258349); length 93.5 mm, height 75.9 mm.
4. *Costaglycymeris* (Dall, 1898)
Left valve of specimen (USNM 258350); length 60.5 mm, height 65.1 mm.
5. *Dallarca virginiae* (Dall, 1898)
Right valve of specimen (USNM 258351); length 82.2 mm, height 57.3 mm.
6. *Lirophora dalli* (Olsson, 1914)
Right valve of specimen (USNM 258352); length 19.3 mm, height 17.2 mm.
7. *Dallarca carolinensis clisea* (Dall, 1898)
Left valve of specimen (USNM 258353); length 42.7 mm, height 44.1 mm.
8. *Glossus fraterna* (Say, 1824)
Left valve of specimen (USNM 258354); length 82.3 mm, height 80.2 mm.
9. *Euloxa latisulcata* (Conrad, 1839)
Left valve of an incomplete specimen (USNM 258355); approx. length 15 mm, approx. height 13.1 mm.
10. *Ostrea compressirostra brucei* Ward, 1992
Left valve of specimen (USNM 258356); length 97.7 mm, height 111.9 mm.
11. *Turritella plebeia carinata* Gardner, 1948
Apertural view of incomplete specimen (USNM 258357); height 24.3 mm.
12. *Chesapecten middlesexensis* (Mansfield, 1936)
Right valve of specimen (USNM 258358); length 98.8 mm, height 91.4 mm.



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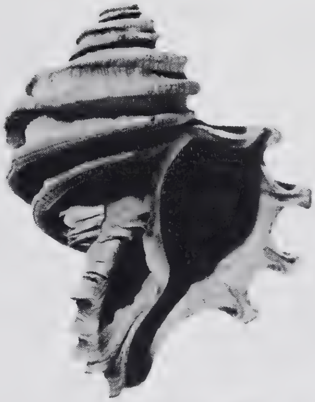

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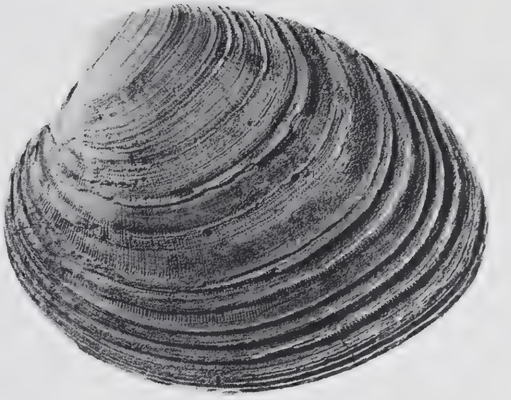

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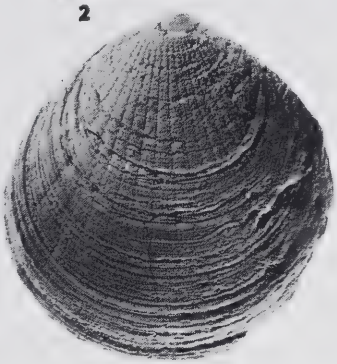

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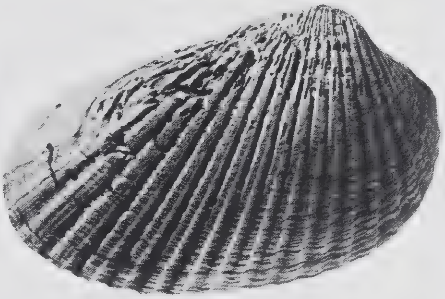

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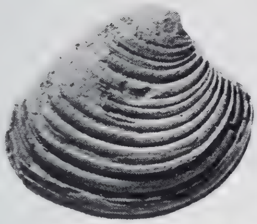

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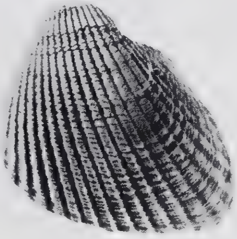

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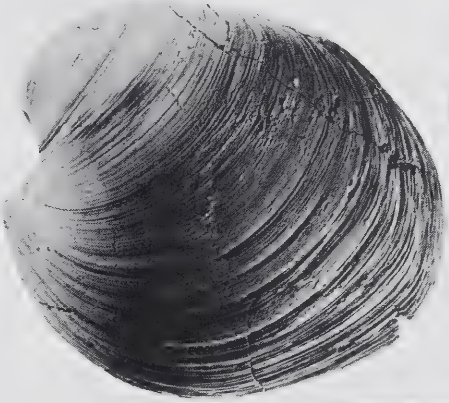

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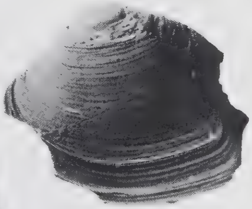

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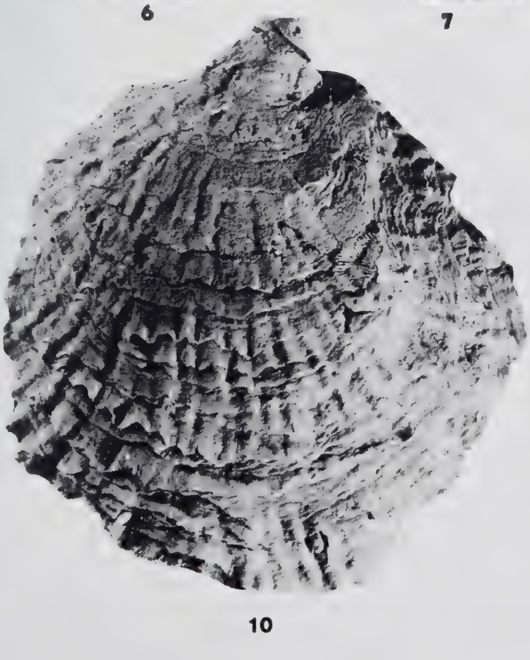

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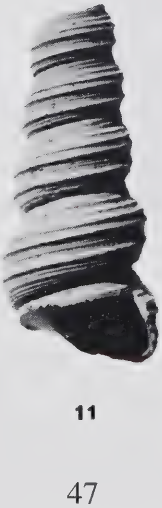

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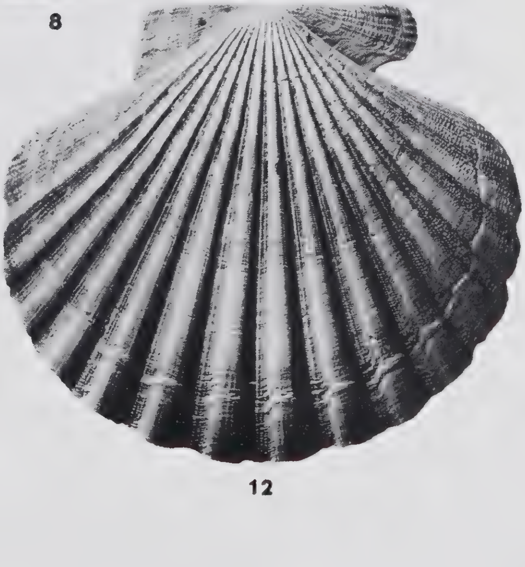

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PLATE 11. Mollusks Common in the Cobham Bay Member of the Eastover Formation

Figure 1. *Placopecten principoides* (Emmons, 1858)

Right valve of a topotype specimen (USNM 258359), from just above Murfreesboro, North Carolina, on the Meherrin River (USGS Locality 26053); length 155.8 mm, height 140.0 mm.

2, 3. *Dallarca carolinensis* (Dall, 1898)

2. Right valve of a complete specimen (USNM 258360), from 2.7 km below Bowlers Wharf on the Rappahannock River, Virginia (USGS Locality 26026); length 44.9 mm, height 46.7 mm.
3. Left valve of same specimen (USNM 258360); length 44.8 mm, height 46.8 mm.

4, 5. *Costaglycymeris mixoni* Ward, 1992.

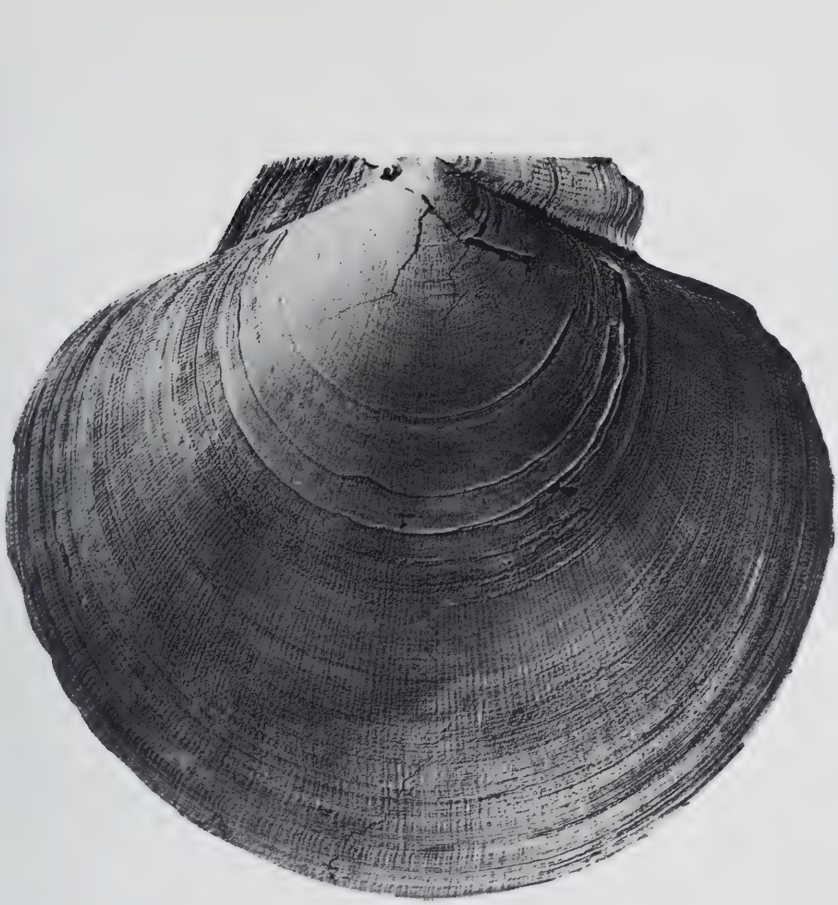
4. Right valve of specimen (USNM 258361), from Cobham Wharf, Virginia (USGS Locality 26052); length 29.2 mm, height 27.9 mm.
5. Dorsal view of a complete specimen (USNM 380782), from the same locality.

6. *Carolinapecten urbannaensis* (Mansfield, 1928)

Right valve of specimen (USNM 258362), from Cobham Wharf, Virginia (USGS Locality 26052); length 77.3 mm, height 73.5 mm.

7. *Chesapecten middlesexensis* (Mansfield, 1936)

Right valve of specimen (USNM 258363) from Urbanna Creek, Middlesex County, Virginia (USGS Locality 26029); length 115.2 mm, height 110.1 mm.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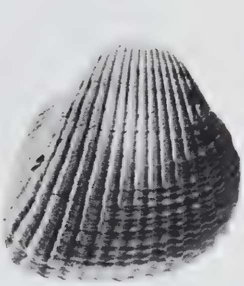
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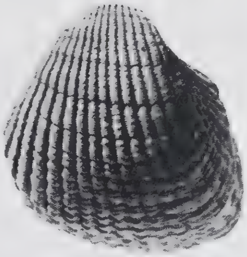
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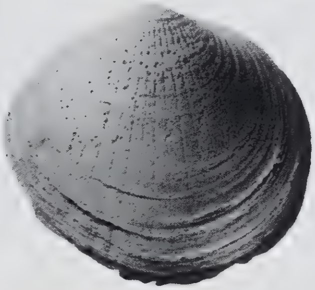
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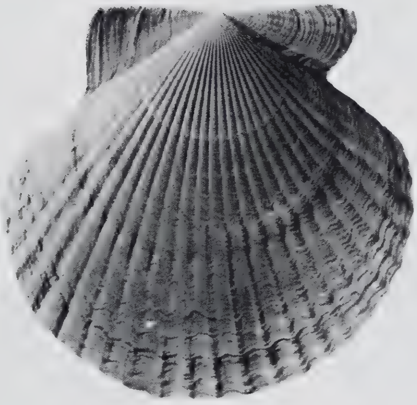
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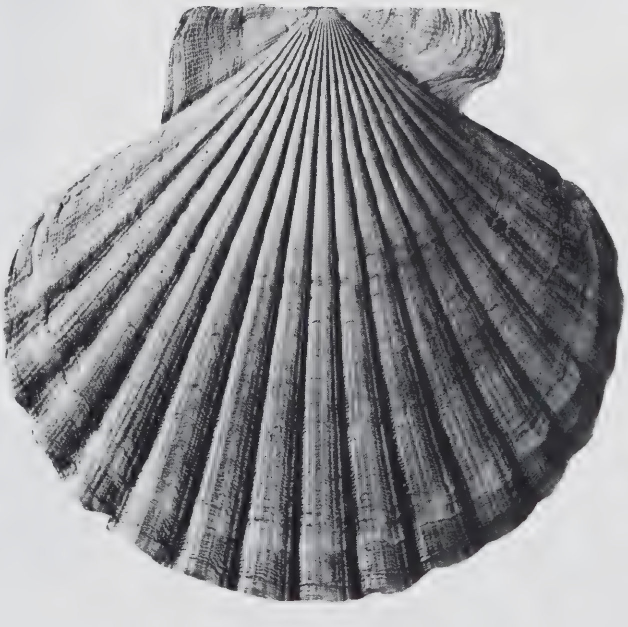
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PLATE 12. Mollusks Common in the Cobham Bay Member of the Eastover Formation

Figure 1. *Hippochaeta* sp.

Right valve of a nearly complete specimen (USNM 258364), from Burhans Wharf on the Rappahannock River, Middlesex County, Virginia (USGS Locality 26062); length 225.0 mm.

2. *Astarte rappahannockensis* (Gardner, 1943)

Left valve of specimen (USNM 258365), from just below Sunken Meadow Creek on the James River, Surry County, Virginia (USGS Locality 26066); length 21.9 mm, height 19.8 mm.

3. *Euloxa Latisulcata* (Conrad, 1839)

Left valve of specimen (USNM 258366), from Cobham Wharf, Virginia (USGS Locality 26052); length 20.9 mm, height 18.9 mm.

4. *Mercenaria* druidi Ward, 1992

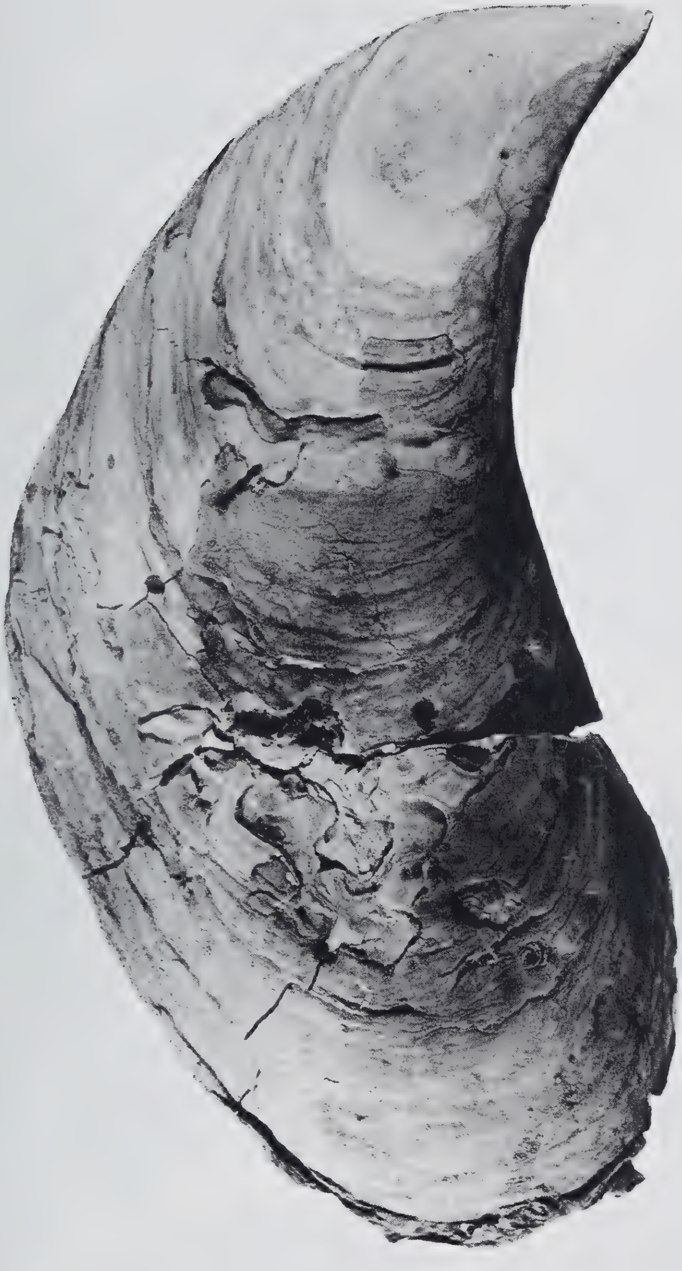
Left valve of specimen (USNM 258367), from Urbanna Creek, just above Urbanna, Middlesex County, Virginia (USGS Locality 26029); length 75.5 mm, height 63.3 mm.

5, 6. *Spisula rappahannockensis* (Gardner, 1943)

5. Left valve of specimen (USNM 258368), from 2.7 km below Bowlers Wharf on the Rappahannock River, Virginia (USGS Locality 26026); length 27.2 mm, height 18.8 mm.
6. Interior of right valve of specimen (USNM 258369), from same locality as that shown in fig. 5; length 28.0 mm, height 19.0 mm.

7. *Ostrea compressirostra geraldjohnsoni* Ward, 1992.

Left valve of specimen (USNM 258370), from Cobham Wharf, Virginia (USGS Locality 26052); length 90.1 mm, height 106.8 mm.



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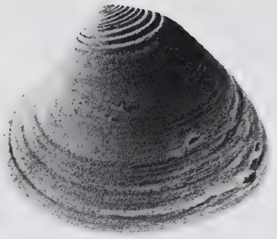

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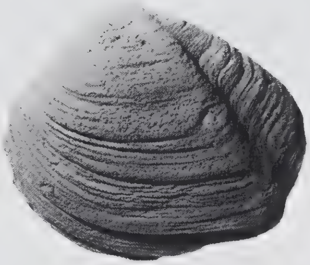

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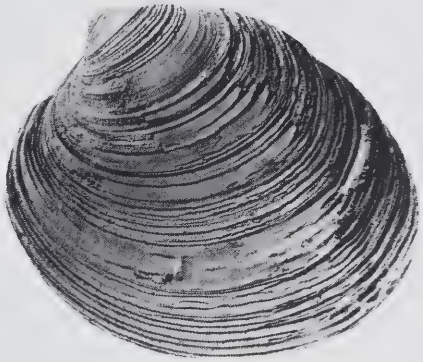

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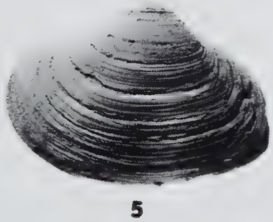

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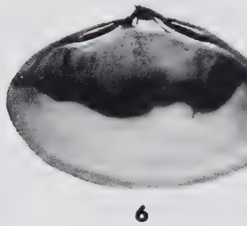

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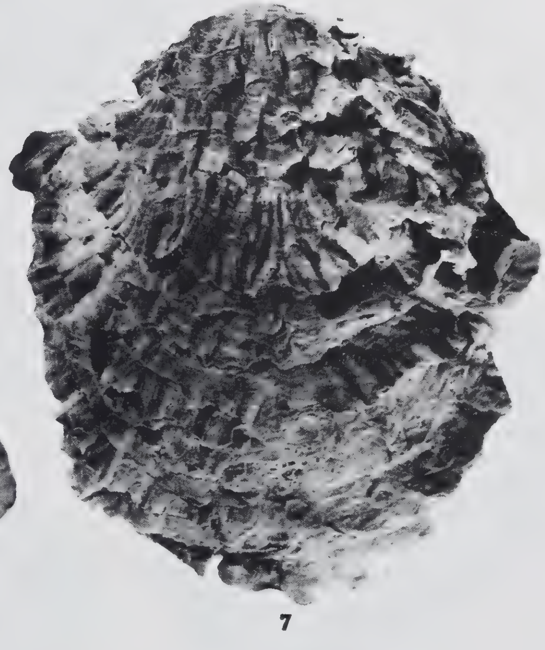

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PLATE 13. Mollusks Common in the Sunken Meadow Member of the Yorktown Formation

Figure 1. *Placopecten clintonius* (Say, 1824)
Right valve of specimen (USNM 258371), from just below Sunken Meadow Creek on the James River, Virginia (USGS loc. 26031), length 129.0 mm, height 127.3 mm.

2. *Chesapecten jeffersonius* (Say, 1824)
Left valve of specimen (USNM 258372) from 1.0 km below Kingsmill Wharf on the James River, Virginia (USGS loc. 26105), length 98.6 mm, height 91.1 mm.

3, 4. *Pycnodonte* sp.
Exterior and interior views of the left valve of a specimen (USNM 258373), from 1 km below Eastover on the James River, Virginia (USGS loc. 26110), length 63.5 mm, height 67.1 mm.

5. *Ostrea compressirostra* (Say, 1824)
Left valve of specimen (USNM 258374) from just below Sunken Meadow Creek on the James River, Virginia (USGS loc. 26031), length 83.2 mm, height 77.8 mm.

6. *Busycon maximum* (Conrad, 1839)
Apertural view of incomplete specimen (USNM 258375), from Martiau on the Piankatank River, Middlesex County, Virginia (USGS loc. 26106), length?, height 92.1 mm.

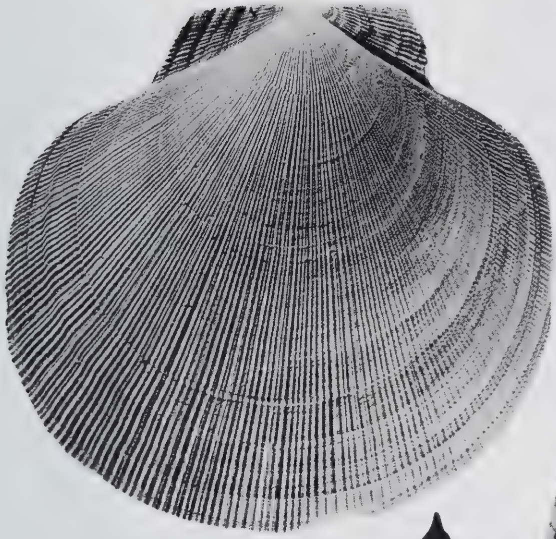
7. *Panopea reflexa* Say, 1824
Left valve of specimen (USNM 258376), from just below Sunken Meadow Creek on the James River, Virginia (USGS loc. 26031), length 124.4 mm, height 74.0 mm.

8. *Mercenaria* sp.
Right valve of specimen, (USNM 258377), from just below Sunken Meadow Creek on the James River, Virginia (USGS loc. 26031), length 108.5 m, height 94.0 mm.

9. *Astarte deltoidea* (Gardner, 1943)
Right valve of specimen (USNM 258379), from just below Sunken Meadow Creek on the James River, Virginia (USGS loc. 26031), length 24.2 mm, height 25.6 mm.

10. *Astarte vaginulata* (Dall, 1903)
Right valve of specimen (USNM 258379) from just below Sunken Meadow Creek on the James River, Virginia (USGS loc. 26031), length 25.3 mm, height 22.0 mm.

11. *Ecphora quadricostata* (Say, 1824)
Apertural view of specimen (USNM 258380), from Haynes Mill, Gloucester County, Virginia (USGS loc. 26111), height 119.8 mm.



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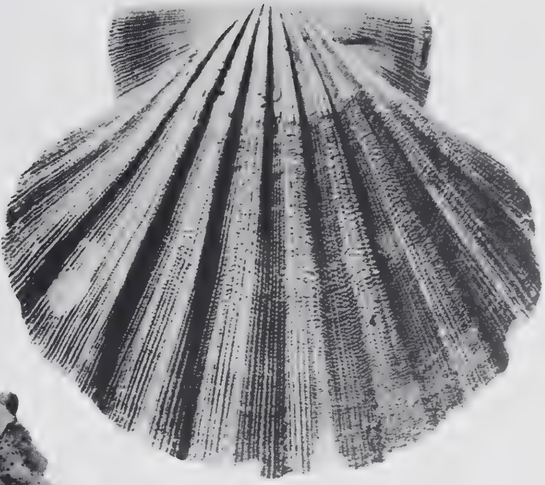

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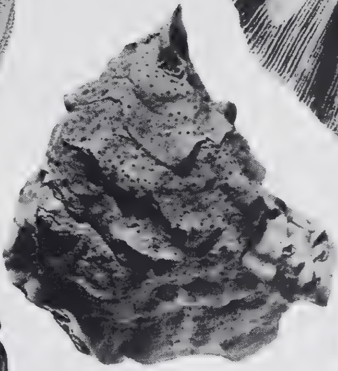

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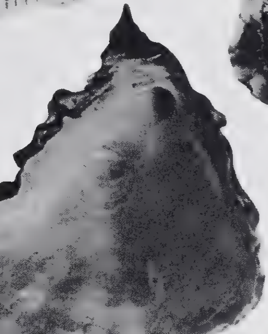

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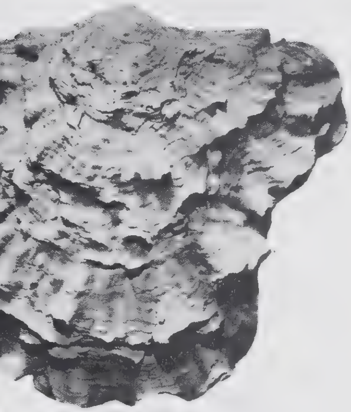

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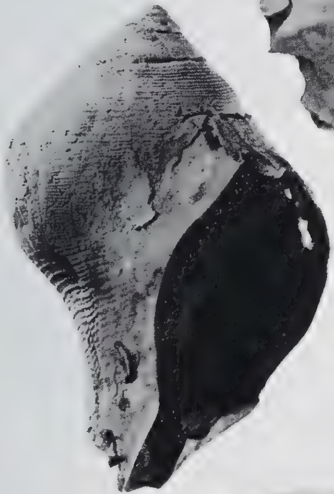

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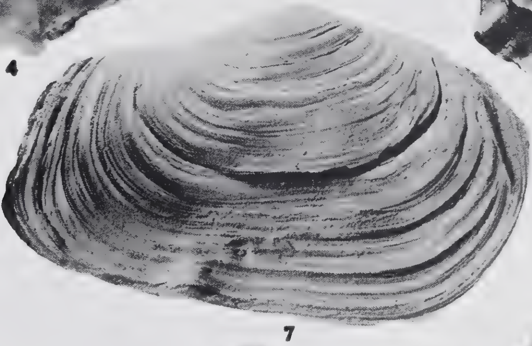

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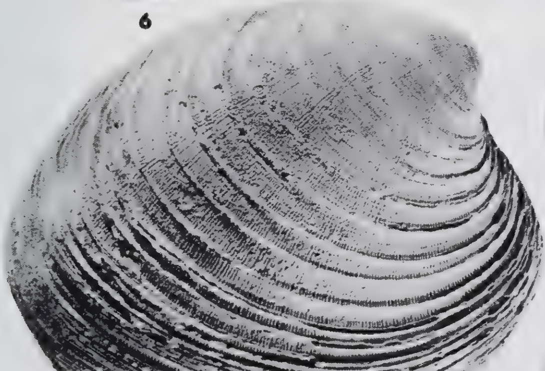

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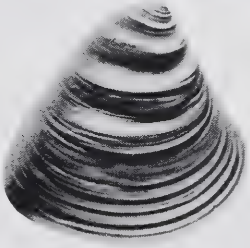

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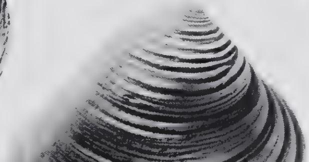

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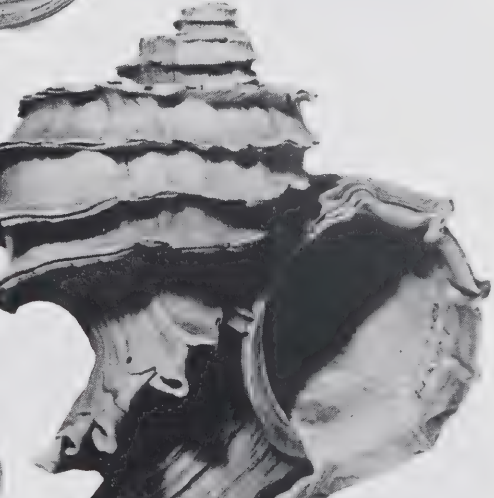

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PLATE 14. Mollusks Common in the Rushmere, Morgarts Beach, and Moore House Members of the Yorktown Formation

Figure 1. *Chesapecten septenarius* (Say, 1824)
Right valve of specimen (USNM 258381) from Lieutenant Run in Petersburg, Virginia (USGS loc. 26067), length 68.8 mm, height 66.3 mm.

2. *Chesapecten madisonius* (Say, 1824)
Right valve of specimen (USNM 258381) from Lieutenant Run in Petersburg, Virginia USGS loc. 26067), length 68.8 mm, height 66.3 mm.

3. *Fusinus exilus* (Conrad, 1832)
Apertural view of specimen (USNM 258383), from 1.0 km below Morgarts Beach on the James River, Virginia (USGS loc. 26079), height 50.3 mm.

4. *Busycon maximum* (Conrad, 1839)
Apertural view of specimen (USNM 258384), from Rices Borrow Pit in Hampton, Virginia (USGS loc. 26112), height 260.0 mm.

5. *Ostrea raveneliana* Tuomey and Holmes, 1855
Left valve of specimen (USNM 258385), from 1.0 km below Morgarts Beach on the James River, Virginia (USGS loc. 26079), length 102.5 mm, height 114.3 mm.

6. *Conradostrea sculpturata* (Conrad, 1840)
Left valve of specimen (USNM 258386), from Rices Borrow Pit in Hampton, Virginia (USGS loc. 26112), length 42.1 mm., height 57.2 mm.

7. *Astarte undulata* (Say, 1824)
Right valve of specimen (USNM 258387), from 1.0 km above Morgarts Beach on the James River, Virginia (USGS loc. 26113), length 28.4 mm, height 26.4 mm.

8. *Costaglycymeris tuomeyi* (Dall, 1898)
Right valve of specimen (USNM 258388 from Morgarts Beach on the James River, Virginia (USGS loc. 26114), length 35.5 mm height 31.8 mm.

9. *Glycymeris americana* (DeFrance, 1826)
Right valve of specimen (USNM 258389), from Morgarts Beach on the James River, Virginia (USGS loc. 26114), length 60.7 mm height 55.6 mm.

10. *Mercenaria tridacnoides rileyi* (Conrad, 1838)
Right valve of specimen (USNM 258390), from Lieutenant Run in Petersburg, Virginia (USGS loc. 26067), length 94.0 mm, height 70.2 mm.

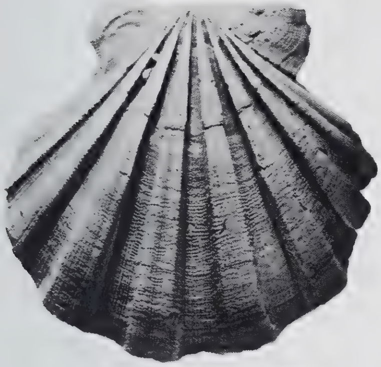
11, 12. *Pseudochama corticosa* (Conrad, 1833)
Exterior and interior views of the right valve of a specimen (USNM 258391), from Morgarts each on the James River, Virginia (USGS loc. 26114), length 46.1 mm, height 51.5 mm.

13. *Astarte concentrica* (Conrad, 1834)
Right valve of specimen (USNM 258392), from Lieutenant Run in Petersburg, Virginia (USGS loc. 26067), length 22.6 mm, height 20.5 mm.

14. *Mulinia congesta* (Conrad, 1833)
Right valve of specimen (USNM 258393), from Waverly, Sussex County, Virginia (USGS loc. 26115), length 17.4 mm, height 12.9 mm.

15. *Mercenaria tridacnoides* (Lamarck, 1818)
Right valve of specimen (USNM 258394), from Lieutenant Run in Petersburg, Virginia (USGS loc. 26067), length 106.1 mm, height 83.8 mm.

16. *Planicardium virginianum* (Conrad, 1839)
Left valve of specimen (USNM 258395), from Rices Borrow Pit in Hampton, Virginia (USGS loc. 26112), length 95.9 mm, height 120.0 mm.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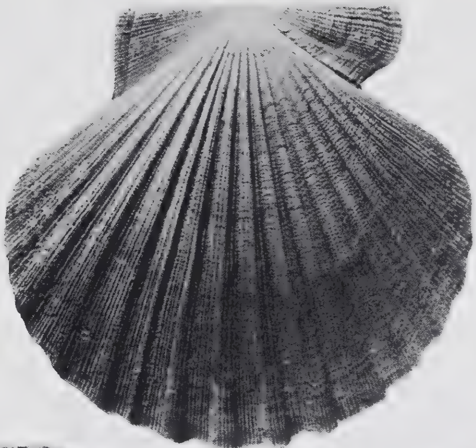
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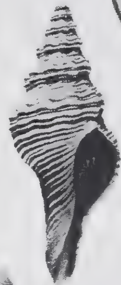
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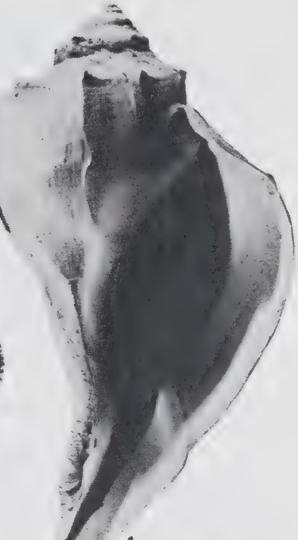
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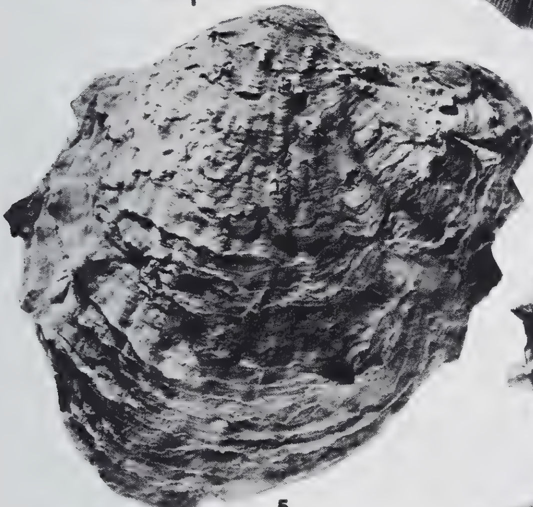
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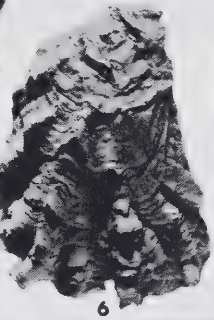
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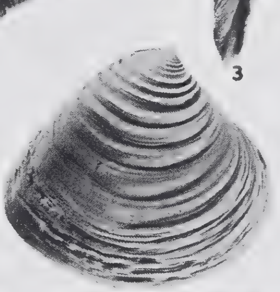
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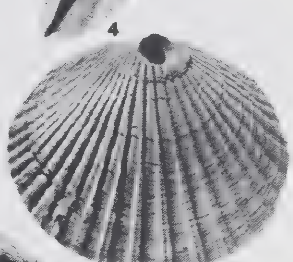
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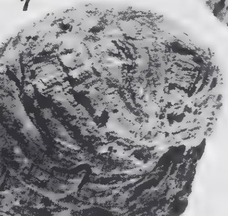
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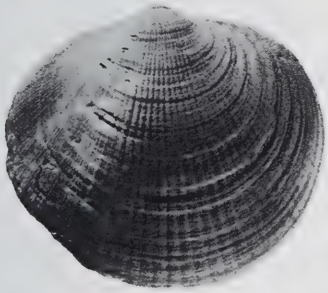
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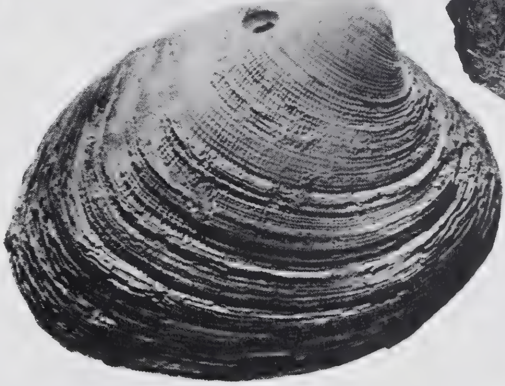
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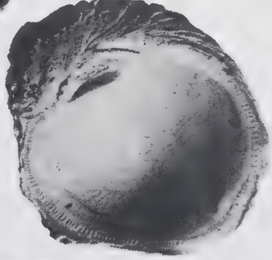
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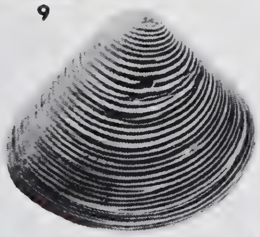
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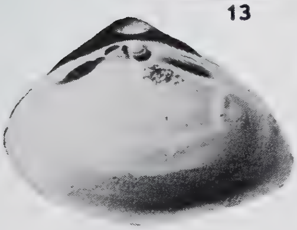
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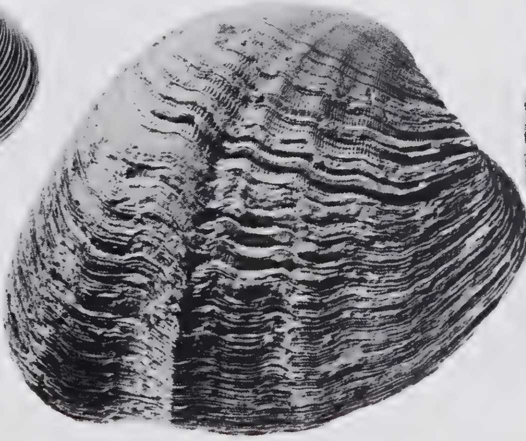
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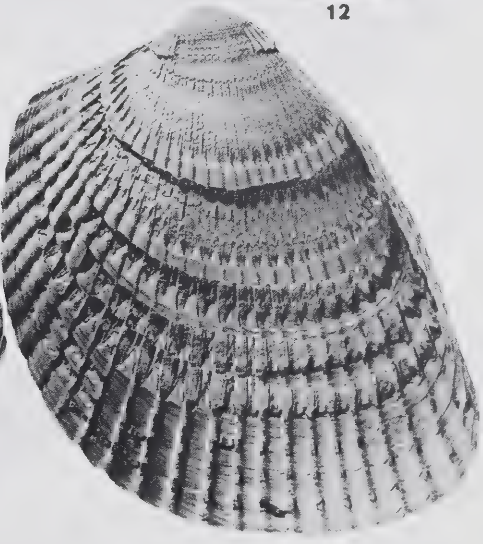
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PLATE 15. Mollusks Common in the Chowan River Formation

Figure 1. *Costaglycymeris hummi* (Ward and Blackwelder).
Left valve. Known only from the Chowan River Formation and its southern equivalent, the Bear Bluff Formation. Last known occurrence of the genus.

2. *Noetia carolinensis* (Conrad).
Left valve. Known only from the Chowan River Formation and its southern equivalent, the Bear Bluff Formation. The species is succeeded in the James City Formation by *N. limula* (Conrad).

3. *Glycymeris americana* (DeFrance).
Left valve. Appears first in the Rushmere Member of the Yorktown Formation, but becomes most abundant in the Chowan River and James City Formations.

4. *Marvacrassatella kauffmani* Ward and Blackwelder
Left valve. First appearance of the species in the Chowan River Formation. Persists into the James City Formation, after which the genus becomes extinct.

5. *Panopea goldfussii* ssp.
Left valve. Closely related to *P. goldfussii* Wagner, which is present in the Calvert, Choptank, St. Marys, Eastover, and Yorktown Formations. Specimens in Chowan River and James City Formations have thin, raised, internal calcareous plaits under the umbo, which may or may not be related to genetic differences.

6. *Ostrea raveneliana.* Tuomey and Holmes.
Right valve. Present, but never abundant, in the Chowan River Formation. Last appearance of the lineage on the North American coast.

7. *Conradostrea sculpturata* (Conrad).
Left valve. First appearance in the Rushmere Member of the Yorktown Formation. Common in the Chowan River Formation. Species is succeeded in the James City Formation by *C. lawrencei* Ward and Blackwelder, the last appearance of the genus.

8. *Carolinapecten eboreus bertiensis* (Mansfield).
Right valve. Extremely common in the Chowan River Formation.

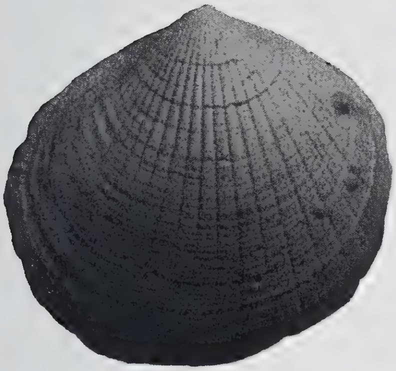
9. *Mercenaria carolinensis* Conrad.
Right valve. First appearance in the Chowan River Formation. Shows none of the variable thickness or the "tridacna"-like irregularly ribbed exterior of the *M. rileyi-M. tridacnoides-M. corrugata* species complex.

10. *Scaphella typus* (Conrad).
First appearance in the Chowan River Formation and last appearance in the James City Formation. The name "typus" was used incorrectly on a species from the Choptank Formation (corrected to *S. virginiana* Dall in Ward, 1992).

11. *Busycotypus concinnum* (Conrad).
First appearance in the Chowan River Formation and last appearance in the James City Formation.

12. *Cyclocardia granulata* (Say).
Left valve. First appearance in the Sunken Meadow Member of the Yorktown Formation. Last appearance in the late Pleistocene.

13. *Astarte concentrica* Conrad.
Left valve. First appearance in the Rushmere Member of the Yorktown Formation. Common in the Chowan River and James City Formations. Not known stratigraphically higher than the James City Formation.



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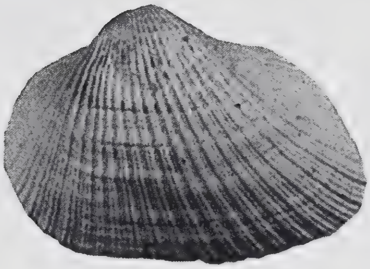

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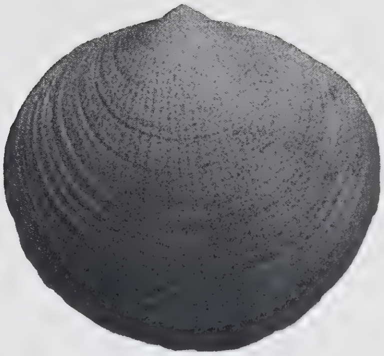

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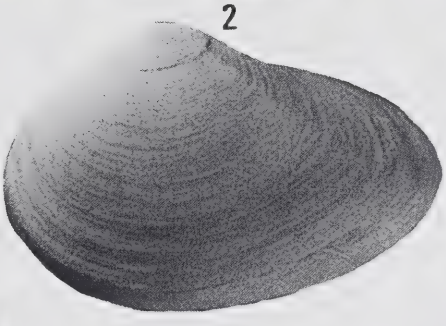

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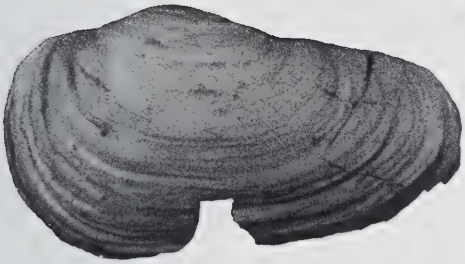

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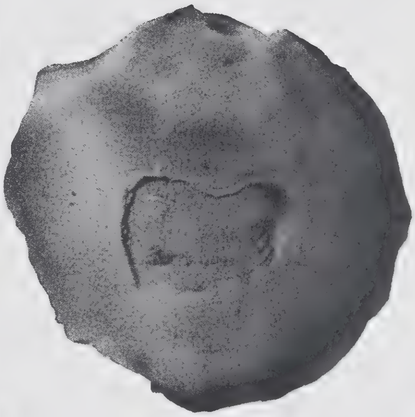

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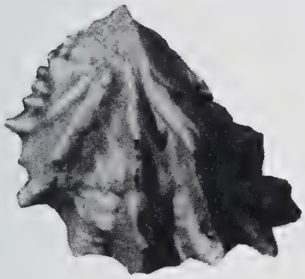

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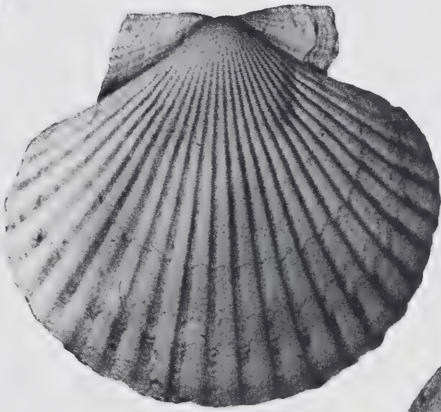

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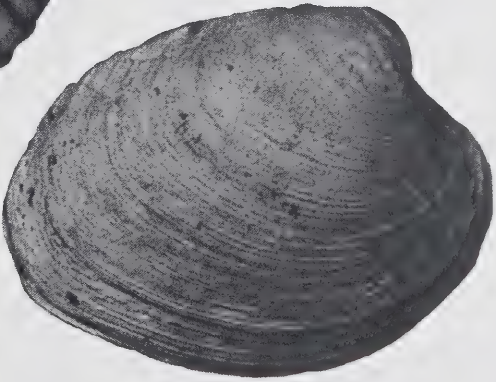

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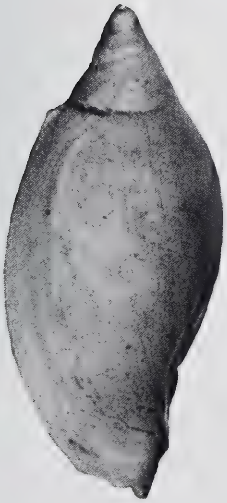

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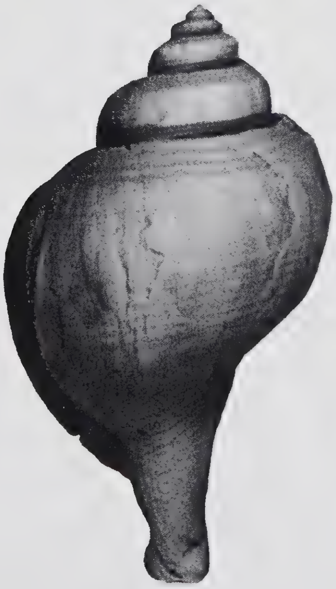

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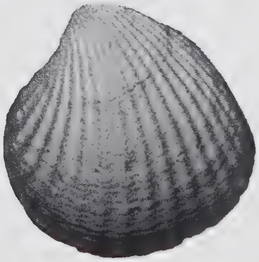

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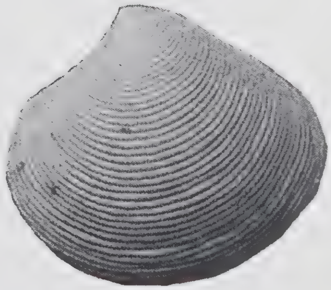

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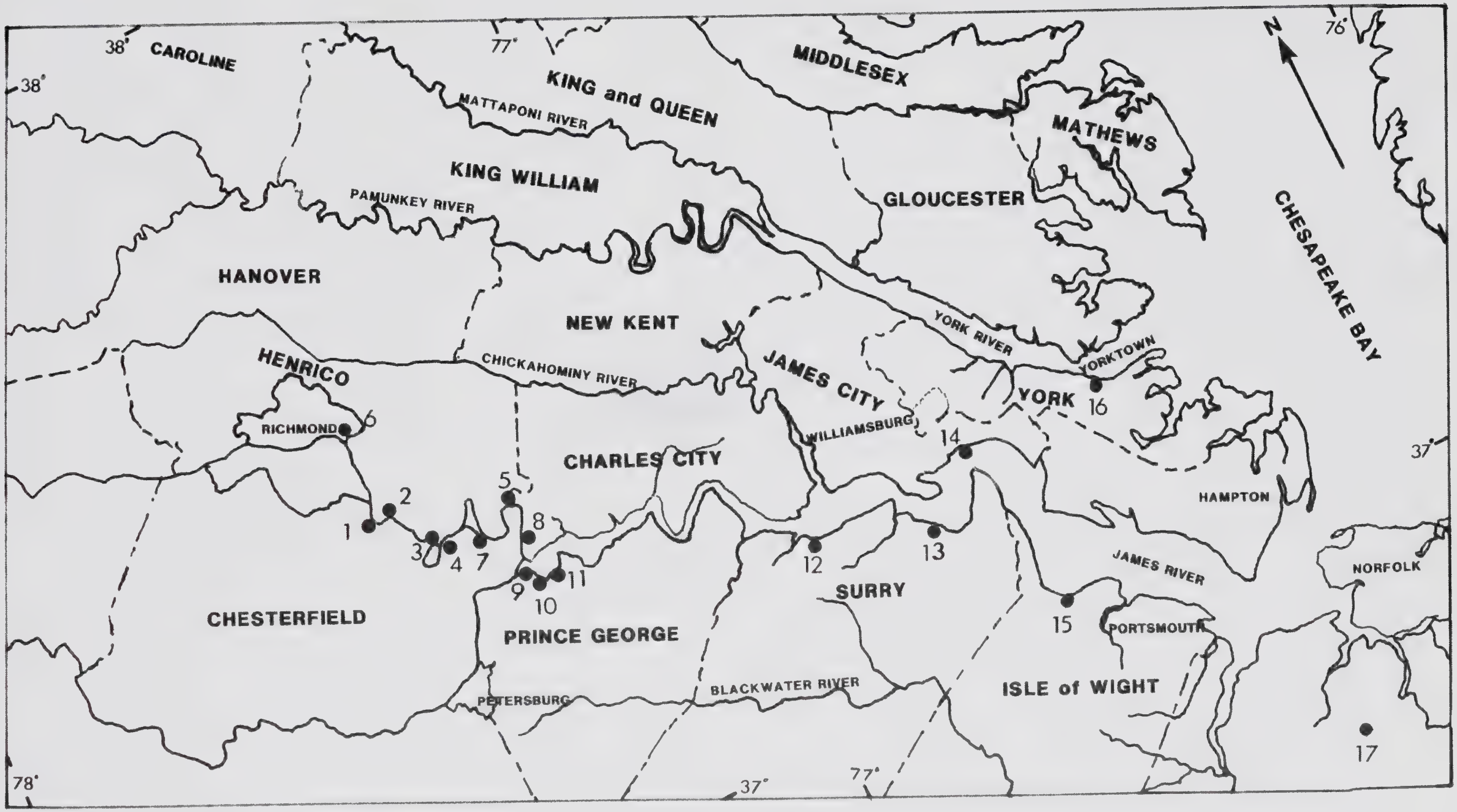
GEOLOGIC SECTIONS
ALONG THE JAMES RIVER
SECTIONS 1-5 ARE FROM BERRY (1912)
SECTIONS 6-17 ARE FROM WARD



GEOLOGIC SECTIONS ALONG THE JAMES RIVER

LOWER CRETACEOUS SECTIONS DESCRIBED BY E. W. BERRY (1912) WITH PRESENT AUTHOR'S NOTES IN [BRACKETS]

At Richmond the crystallines are exposed in the bed of the river, and their contact with the Patuxent is not seen because of the low banks which are continuous for several miles below that town. Several low bluffs along the left bank between Richmond and Drewry's Bluff show a few feet of Patuxent arkosic argillaceous sands beneath 10 to 20 feet of Pleistocene. The section of Drewry's Bluff shows the best exposure of the Patuxent formation on the river and is continuous along the right bank for over half a mile. The lateral variation of the materials is considerable and affords an excellent idea of the marked changes in lithology which are typical of the Patuxent, particularly in this area.

[Locality 1] *Section at Drewry's Bluff*

		Feet
Pleistocene	Argillaceous, ferruginois sand	6
	Gravel bed	5
Lower Cretaceous. Patuxent	Light gray coarse, arkosic sand	5-20
	Similar materials much cross-bedded and carrying gravel, cobbles, and clay balls	5-15
	Dark drab clay lenses in sand	5-10
	Indurated arkosic sand	12
	Coarse, arkosic, cross-bedded sand with clay balls and cobbles	15
	Total	53-83

As previously mentioned, the materials change so rapidly from point to point that no two sections of the bluff would be identical. The clay lens near the middle of the outcrop is very variable and the cobbles frequently tend to become aggregated into lenticular masses. Indurated layers a foot or two in thickness are also irregularly scattered through the bluff.

The next exposure is at Chaffin Bluff along the left bank one mile below the last.

[Locality 2] *Section at Chaffin Bluff*

		Feet
Pleistocene	Ferruginous, sandy clay	15
	Bed of cobbles	5
Lower Cretaceous. Patuxent	Gray, arkosic sand	10
	Dark drab clay	15
	Total	45

This section also is extremely variable horizontally.

The next exposure about three miles below the last is along the right bank a short distance below Proctor Creek where the Patuxent is overlain by a remnant of Eocene [Paleocene] materials.

[Locality 3] *Section below Proctor Creek*

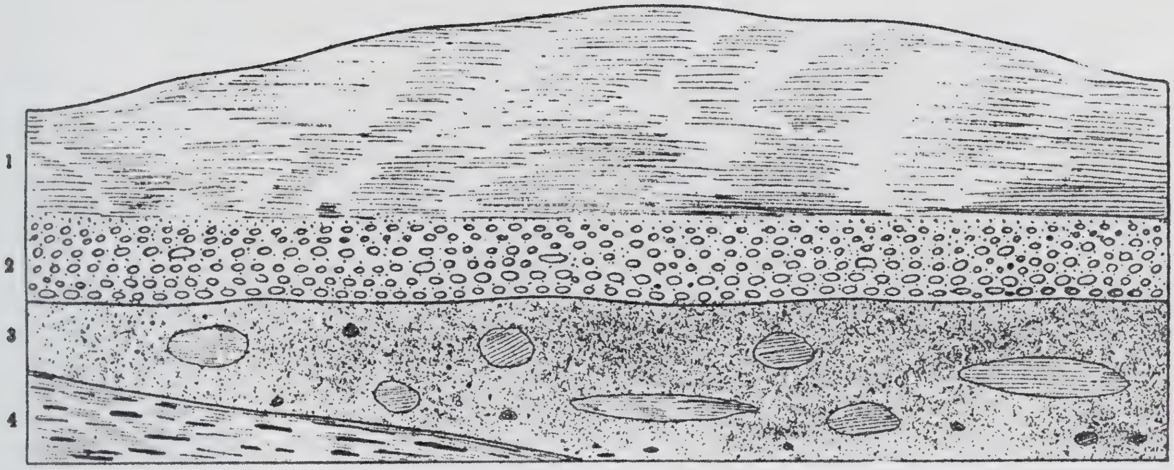
		Feet
Pleistocene	Argillaceous, ferruginous sand	about 10
	Course [sic] gravel with cobbles	8-10
Eocene	Glauconitic sands	5
Lower Cretaceous. Patuxent	Indurated, coarse, arkosic, cross-bedded sands	10-15
	Total	33-40

Below this exposure a short distance the crystallines show along the right bank, and they are also exposed in the bed of a small stream which flows into the left bank about one and a half miles above Dutch Gap canal, these limited outcrops constituting the most easterly appearance of the Piedmont rocks in this area.

For about two miles before reaching Dutch Gap canal low exposures of the Patuxent formation overlain by a considerable thickness of Pleistocene are exposed along the left bank. The materials are grayish arkosic, cross-bedded sands with numerous clay lenses, some of which have yielded fossil plants, notably a low exposure about one mile above the canal where the following species have been collected:

Abietites longifolius (Font.) Berry
Abietites foliosus (Font.) Berry
Abietites macrocarpus Font.
Acrostichopteris pluripartita (Font.) Berry
Acrostichopteris cyclopteroides Font.
Acrostichopteris parvifolia Font.
Baiera foliosa Font.
Carpolithus virginiensis Font.
Carpolithus geminatus Font.
Carpolithus latus Font.
Carpolithus sessilis Font
Ceptalotaxopsis brevifolia Font.
Cephalotaxopsis magnifolia Font.
Cladophlebis virginiensis Font.
Cladophlebis distans Font.
Cladophlebis Browniana (Dunk.) Seward.
Cladophlebis Ungeri (Dunk.) Ward
Cladophlebis Albertsii (Dunk.) Brongn.
Cladophlebis oblongifolia Font.
Cladophlebis sphenopteroides Font.
Cycadeospernum ellipticum Font.
Dioonites Buchianus (Ett.) Born
Equisetum Burchardti (Dunk.) Brongn.
Equisetum Lyelli Mant.
Ficophyllum crassinerve Font.
Gleichenia nordenskioldi Heer
Nageiopsis longifolia Font.
Nageiopsis zamioides Font.
Onychiopsis Goepperti (Schenk) Berry
Phyllocladopsis heterophylla Font.
Podozamites acutifolius Font.
Proteaephyllum tenuinerve Font.
Rogersia longifolia Font.
Ruffordia acrodentata (Font.) Berry
Ruffordia Goepperti (Dunk.) Seward
Sclеropteris elliptica Font.
Sphenolepis Kurriana (Dunk.) Schenk
Sequoia ambigua Heer
Sequoia delicatula Font.
Thinnfeldia granulata Font.
Thyrsopteris brevipennis Font.
Thyrsopteris divaricata Font.
Thyrsopteris meekiana Font.
Thyrsopteria anguistifolia Font.
Thyrsopteria angustiloba Font.
Thyrsopteris nana Font.
Thyrsopteria ineaquipinnata Font.
Williamsonia virginiensis Font.
Zamites crassinervis Font.
Zamites tennuinervis Font.

Dutch Gap Canal, celebrated historically, is 17 miles below Richmond. It is only about 100 yards in length and cuts off an oxbow of seven miles. Low exposures of Patuxent materials are equally well exposed in both banks and show in the following section, the following figure, a diagrammatic representation of the east bank.



Dutch Gap Canal. Diagrammatic representation of the east bank.

[Locality 4] ***Section on Dutch Gap Canal***

[This locality, probably one of the most important for the Cretaceous east of the Mississippi River, has been destroyed by riprapping for a park/golf course since 1997.]

		Feet
Pleistocene	1. Argillaceous sand grading down into gravel	20
	2. Cobble bed	5
Lower Cretaceous. Patuxent	3. Coarse, arkosic gray sand with numerous pebbles, clay pellets, and clay balls. The latter are barren dark drab clay or hard brown clay or somewhat sandy brown clay with leaf impressions. Occasional lenses of sandy brown clay, indistinctly laminated carry good leaf impressions including *Acrostichopteris parvifolia* Font. *Acrostichopteris pluripartita* (Font.) Berry, *Arthrotaxopsis grandis* Font., *Cladophlebis oblongifolia Font.,* *Cladophlebis distans.* Font., *Cladophebis Browniana* (Dunk.) Seward, *Dioonites Buchianus* (Ett.) Born., *Dryopteria dentatum* Font., *Dryopteris macrocarpum* Font., *Leptostrubus foliosus* Font., *Nageiopsis longifolia* Font., *Nageiopsis zamioides.* Font., *Onychiopsis Goepperti* (Schenk) Berry, *Osmunda sphenopteroides* Font *Scleropteris elliptica* Font., *Sequoia Reichenbachi* (Gein) Heer,	

Sphenolepis Kurriana Schenk,
Thyrsopteris brevifolia Font.,
Thyrsopteris brevipennis Font.,
Thyrsopteris dentata Font.,
Thyropteris divaricata Font.,
Thyropteris obtusilobata Font.,
and *Zamites tenuinervis* Font. 0-9

4. Dark drab stratified, pyritiferous and lignitic clays 0-6

Total 26-3

Above the lower entrance to the canal along the right bank of the old river channel the Potomac Group is exposed more or less continuously for a distance of between 3 and 4 miles as far as the Howlett House bluff. At this point the following section is seen:

Section at Howlett House Bluff. [This Section is Now Covered.]

		Feet
Pleistocene. Sunderland	Yellowish sandy loam	about 45
Miocene. Calvert	Fine yellow sand clay	about 35
Eocene. Aquia	Glauconitic argillaceous sand becoming indurated below	15
Lower Cretaceous. Patuxent	Coarse gravelly sand	10
	Cross-bedded, arkosic sand	18
	Similar materials with cobbles. Indurated in places	2
	Total	125

Between this point and the lower entrance to the canal clay lenses of very limited extent, and clay balls, have furnished the following fossil plants:

Acrostichopteris parvifolia Font.
Acrostichopteris pluripartita (Font.) Berry
Araucaria obtusifolia Font.
Araucarites virginious Font.
Brachyphyllum crassicaule Font.
Cladophlebis Albertsii (Dunk.) Brogn.
Cladophlebis Browniana (Dunk.) Seward.
Cladophlebis Ungeri (Dunk.) Ward
Dioonites Buchianus (Ett.) Born.
Frenelopsis parceramosa Font.
Onychiopsis Goepperti (Schenck) Berry
Ruffordia Goepperti (Dunk.) Seward.
Sphenolepis Kurriana (Dunk.) Schenk
Thyrsopteris angustifolia Font.
Thyrsopteris angustiloba Font.
Thyrsopteris rarinervis Font.
Williamsonia virginiensis Font.

The next and last exposure of Potomac Group on the James River is at Deep Bottom, 4 miles below Dutch Gap on the left bank just below Three Mile Creek. At this point the following section is seen in the ravine of the creek.

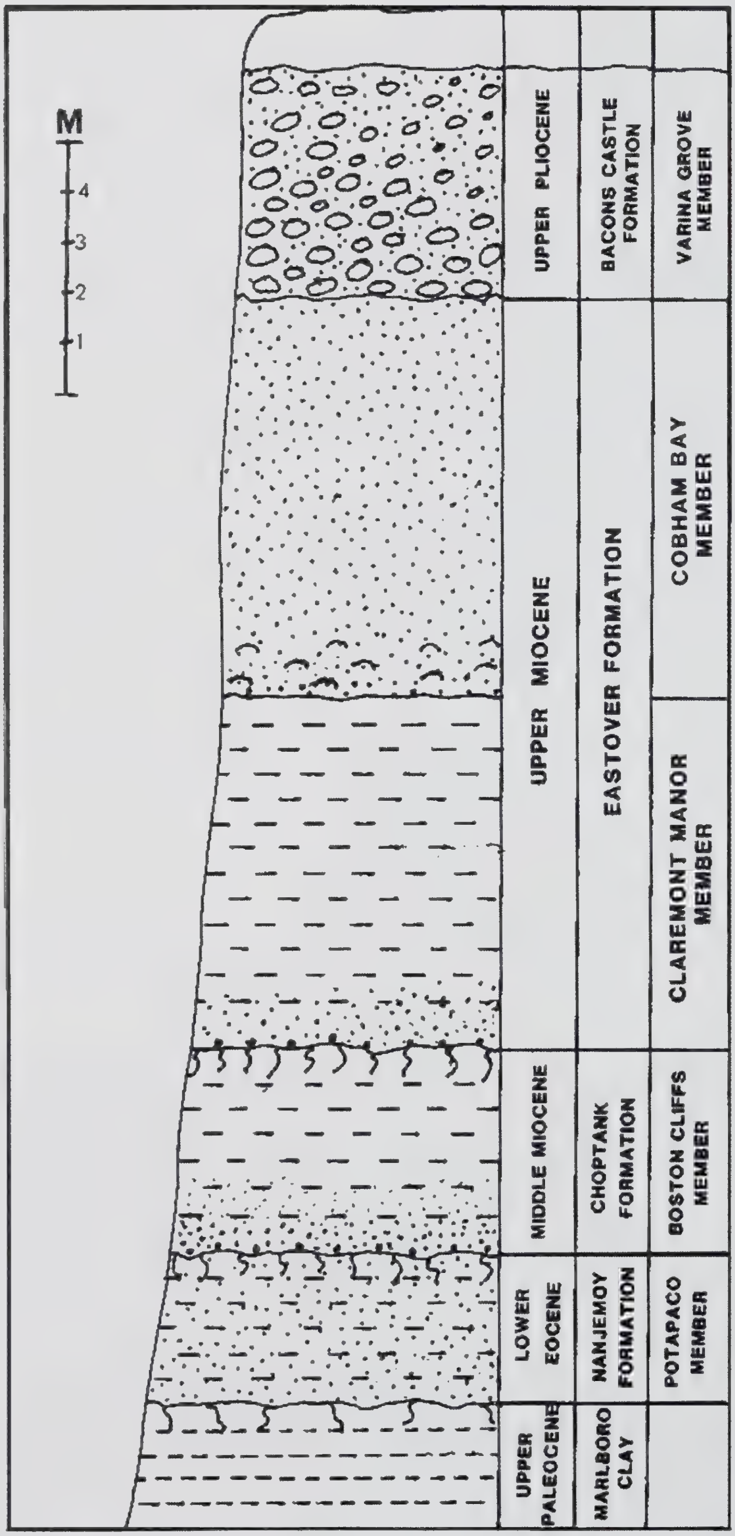
[Locality 5] *Section at Deep Bottom*

		Feet
Pleistocene	Argillaceous sand and loam	10-20
	Gravel bed	5-10
Eocene	Glauconitic argillaceous sand	4-5
Lower Cretaceous. Patapsco	Exposed about	3
	Arkosic sand with cobbles above and containing lenses and balls of sandy brownish clay carrying leaf impressions including *Araliaephyllum* crassinerve (Font.) Berry, *Cladophlebis constricta* Font., *Ficophyllum crassinerve* Font., *Juglandiphyllum integrifolium* Font., *Nageiopsis longifolia* Font., *Podozamites acutifolius* Font., *Populophyllum crassinerve* Font., *Sapindopsis magnifolia* Font., *Sassafras bilobata* Font., *Sphenopteris latiloba* Font., *Sterculia elegans* Font., *Thyrsopteris brevipennis* Font., and *Ulmiphyllum crassinerve* Font.	____
	Total	22-38

TERTIARY SECTIONS DESCRIBED BY WARD (1980, 1984, 1985, ETC.)

Locality 6

P Street Landfill, Richmond, Virginia



Conglomerate, pebbly, cobbly, sandy; sand coarse and current-bedded; some concentrations of sorted, flat-lying clasts.

Sand, greenish-gray (5 GY 3/1), silty, glauconitic near base, pebbly near base, molluscan Molds abundant.

Silty, greenish-gray (5 GY 3/1), clayey, sandy and pebbly near base; Lignitized wood common.
Bone, shark teeth.

Silt, olive-brown (5 Y 2/1), clayey; sandy and pebbly near base, blocky, massive.

Sand, olive-black (5 Y 2/1), silty, clayey, glauconitic. Molds of mollusks.

Clay, gray, silty, weathered, fractured. Base not exposed.

Locality 7

Right bank of the James River, 1.0 mile (1.6 km) above the mouth of the Turkey Island Cutoff, just above Fishpond, Chesterfield County, Virginia, Hopewell 7.5-min quadrangle (see fig. 12)

	Ft	*(m)*
Covered	2.0	(0.6)
Pleistocene (?)		
(?) Formation		
Clay, white, sandy, weathered	14.0	(4.3)
-Unconformity?-		
(?) Formation		
Conglomerate, weathered, grayish-yellow, sand, gravel, cobbles, some reworked glauconitic sand	2.5	(0.8)
-Unconformity?-		
Aquia Formation (Piscataway Member)		
Sand, olive-gray (5 Y 4/1, medium to fine, clayey, glauconitic, poorly sorted; contains numerous mollusks, moderately preserved (*Crassatellites, Turritella, Ostrea)*	2.0	(0.6)
Cobbles, sand and gravel conglomerate; glauconitic, contains shark teeth	1.0	(0.3)
-Sea Level-		

Locality 8

Left bank of the James River, 1.1 miles (1.8 km) above Shirley Plantation, Charles City County, Virginia, Hopewell 7.5-min. quadrangle

	Ft	*(m)*
Covered	20.0	(6.1)
Aquia Formation (Paspotansa Member)		
Sand, olive-gray (5 Y 4/1), somewhat weathered well-sorted, fine, micaceous, glauconitic, some carbonaceous material; molds of *Turritella* and *Crassatellites alaeformis*	6.0	(1.8)

Locality 9

City Point, right bank of the James River at the mouth of the Appomattox River, Hopewell, Prince George County, Virginia. Hopewell 7.5-min. quadrangle

	Ft	*(m)*
Covered	25.0	(7.6)
Aquia Formation (Paspotansa Member)		
Sand, dark-olive-black (5 Y 2/1), fine, micaceous, leached	3.0	(0.9)

Locality 10

Right bank of the James River, just below the mouth of Bailey Creek, Prince George County, Virginia, Westover 7.5-min quadrangle

	Ft	*(m)*
Covered (sloped)	20.0	(6.1)
Marlboro Clay		
Clay, pink (10 R 7/4) in lower one-third, gray (N 7) in upper two-thirds, gypsum crystals common throughout; rare small gastropod molds	10.0	(3.0)
–Unconformity–		
Aquia Formation (Paspotansa Member)		
Sand, fine, well-sorted, glauconitic, weathered, reddish-yellow, somewhat indurated	0.5	(0.2)
Sand, olive-black (5 Y 2/1), fine, silty, micaceous, well-sorted, glauconitic, scattered poorly preserved *Turritella* and *Crassatellites*	12.0	(3.7)
Sand, olive-black (5 Y 2/1), fine, weathered, well-sorted, glauconitic; shell material poorly preserved, numerous *Turritella, Ostrea*	5.0	(1.5)
–Sea Level–		

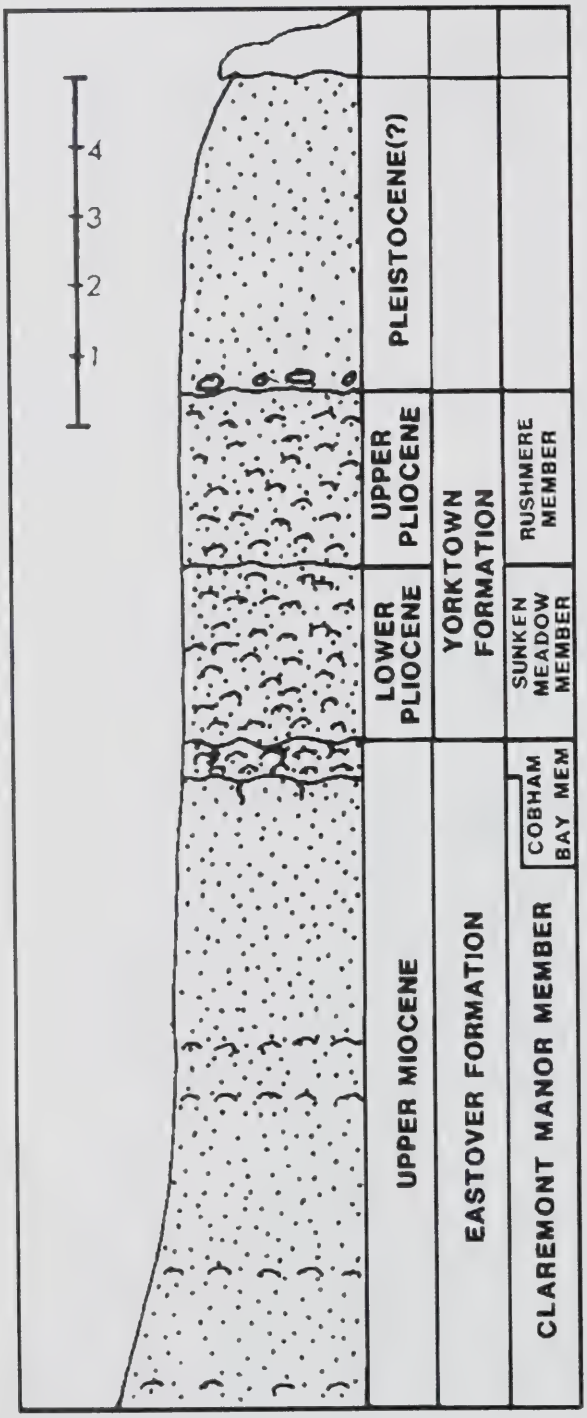
Locality 11

Right bank of the James River, in a ravine downriver from the mouth of Baileys Creek at the northern termination of Route 644, 1.40 miles (2.25 km) (straightline) above Jordan Point, Prince George County, Virginia, Westover 7.5-min quadrangle

	Ft	*(m)*
Covered	50.0	(15.2)
Yorktown Formation (Morgarts Beach Member)		
Clay, blue-gray (4 B 4/1), silty; shells small and mostly leached	15.0	(4.6)
–Grades sharply–		
Yorktown Formation (Rushmere Member)		
Sand, blue-gray (5 B 5/1), medium, quartz; numerous large bivalves, especially *Chesapecten madisonius* and *Mercenaria tridacnoides*	4.0	(1.2)
–Unconformity–		
Eastover Formation (Cobham Bay Member)		
Sand, blue-gray (5 B 5/1) where fresh, medium, quartz, phosphatic; numerous large bivalves (*Hippochaeta, Chesapecten middlesexensis, Euloxa)*	1.0	(0.3)
–Unconformity–		
Nanjemoy Formation (Woodstock Member)		
Sand, olive-black (5 Y 2/1), silty, very fine, micaceous; mollusks common, poorly preserved	12.0	(3.7)
Covered	20.0	(6.1)

Locality 12

1.3 km below the mouth of Sunken Meadow Creek, Claremont, Surry County, Virginia



Sand, gravelly, coarse, with cobbles along the base.

Sand, grayish yellow (5 y 8/4), fine, silty, moderately sorted.

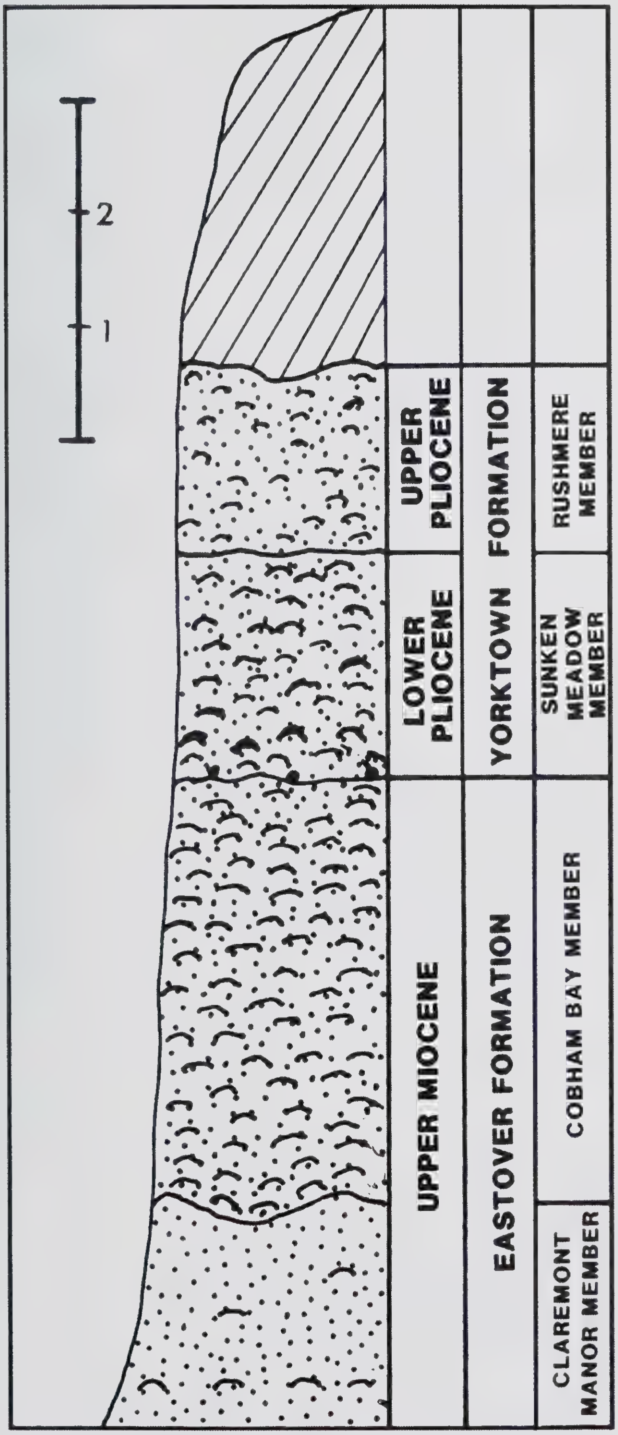
Sand, grayish yellow (5 y 8/4), fine well sorted; very shelly, bone, pebbles, along base.

Sand, grayish yellow (5 y 8/4), fine, well sorted, very shelly.

Sand, greenish-gray (5 GY 3/1), silty, fine, poorly sorted, mollusks concentrated in several thin beds.

Locality 13

Cobham Wharf, 0.8 km below the Old Wharf, Surry County, Virginia



Sand, grayish yellow-fine, clayey, phosphatic, partially indurated and leached.

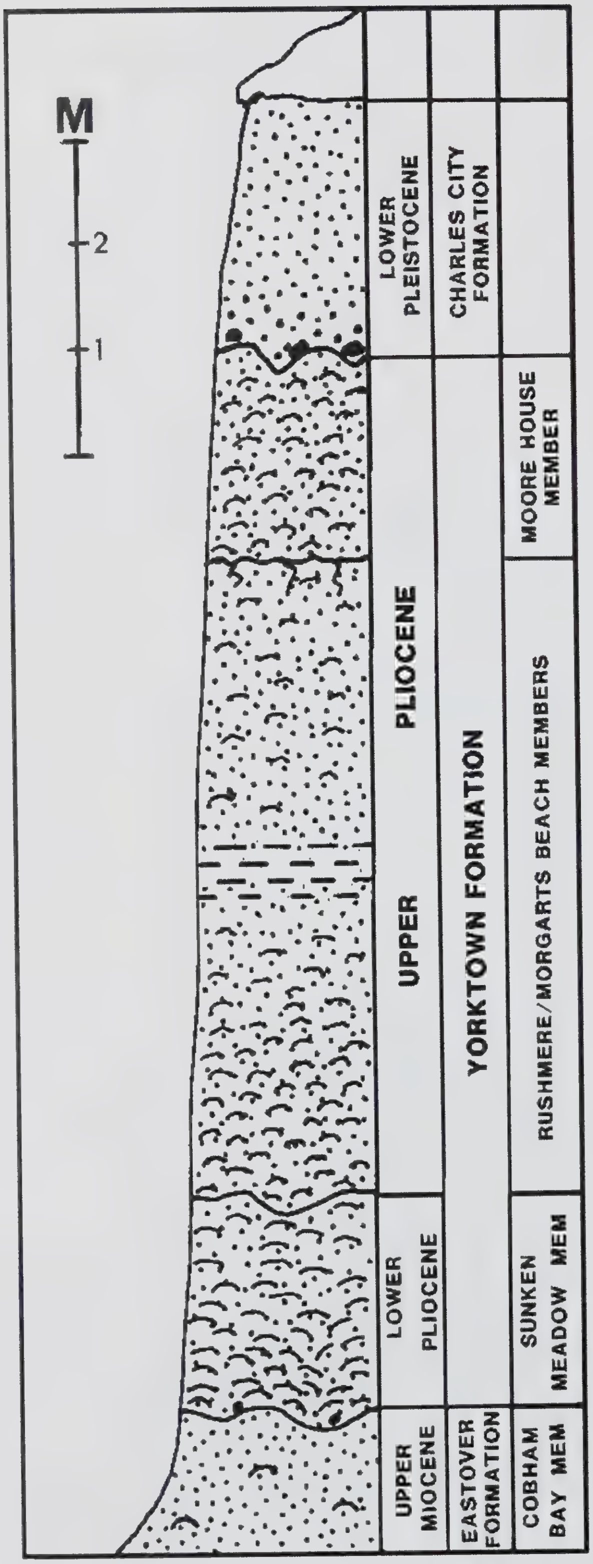
Sand, grayish yellow, fine, well sorted, very shelly, bone, and teeth along lower contact.

Sand, grayish yellow (5 y 8/4), fine, well-sorted; very shelly, lower contact undulant with as much as 0.5m of relief.

Sand, greenish-gray (5 GY 3/1), silty, clayey, poorly sorted, with many echinoid spines; mollusks common.

Locality 14

Kingsmill on the James, James City County, Virginia



Sand, moderate yellow (5 Y 7/6), pebbly, cobbly, somewhat cross-bedded.

Sand, yellowish-gray (5 Y 8/1), fine quartzose, bioclastic, very shelly; much sand-sized shell debris.

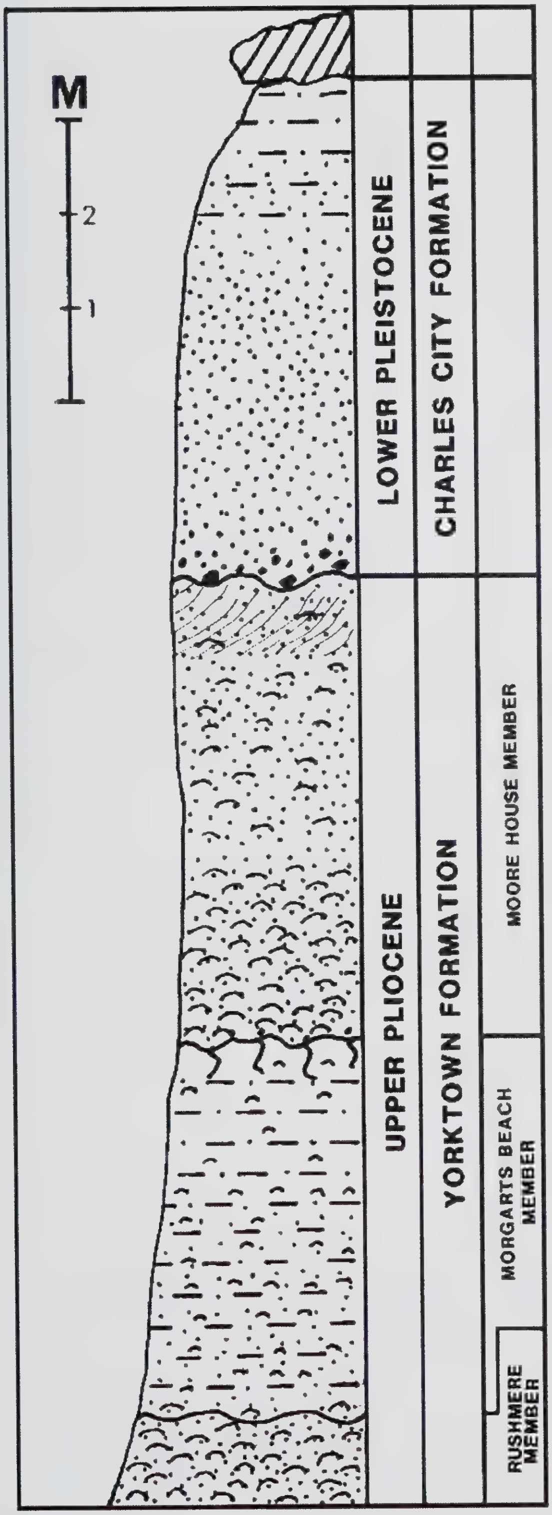
Sand, yellowish-gray (5 Y 8/1), fine silty, many mollusks; *Chama congregata* dominate in lower half; thin tongue of clayey silt near middle is the Morgarts Beach facies. Above and below this clay is the typical Rushmere facies.

Sand, yellowish-gray (5 Y 8/1), fine, silty, very many mollusks, becoming very concentrated in upper half. Mollusks appear current-oriented.

Sand, yellowish-gray (5 Y 8/1), well-sorted, fine few poorly preserved mollusks.

Locality 15

Fort Boykins Park, Isle of Wight County, Virginia



Sand, light yellowish-brown (10 YR 6/3), fine, silty, pebbles and cobbles along contact, grading to silt above.

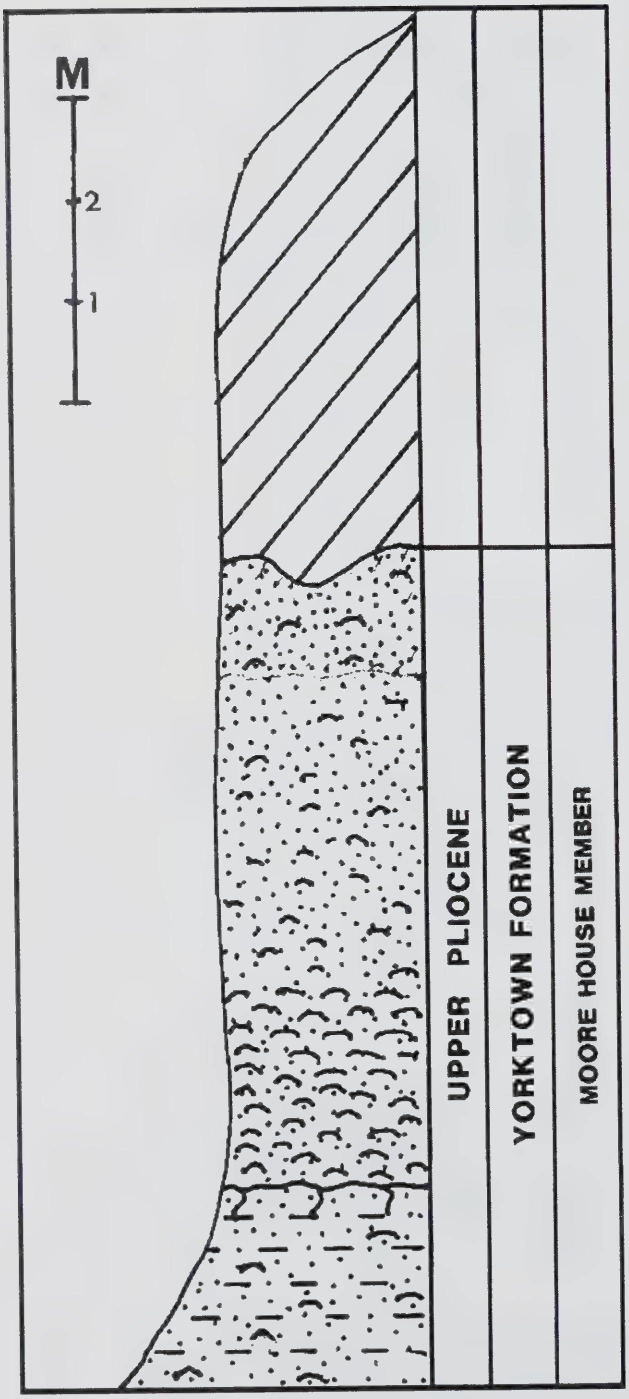
Sand, grayish-yellow (5 Y 8/4), fine quartzose, bioclastic; very shelly, much sand-sized shell debris.

Sand, greenish-gray (5 GY 5/1), very fine, very silty, with small mollusks concentrated in thin beds; *Mulinia congesta* dominant mollusk.

Sand, greenish-gray (5 GY 5/1), fine, clayey, silty, very shelly, diverse molluscan assemblages.

Locality 16

Moore House, Colonial National Historical Park, Yorktown, York County, Virginia

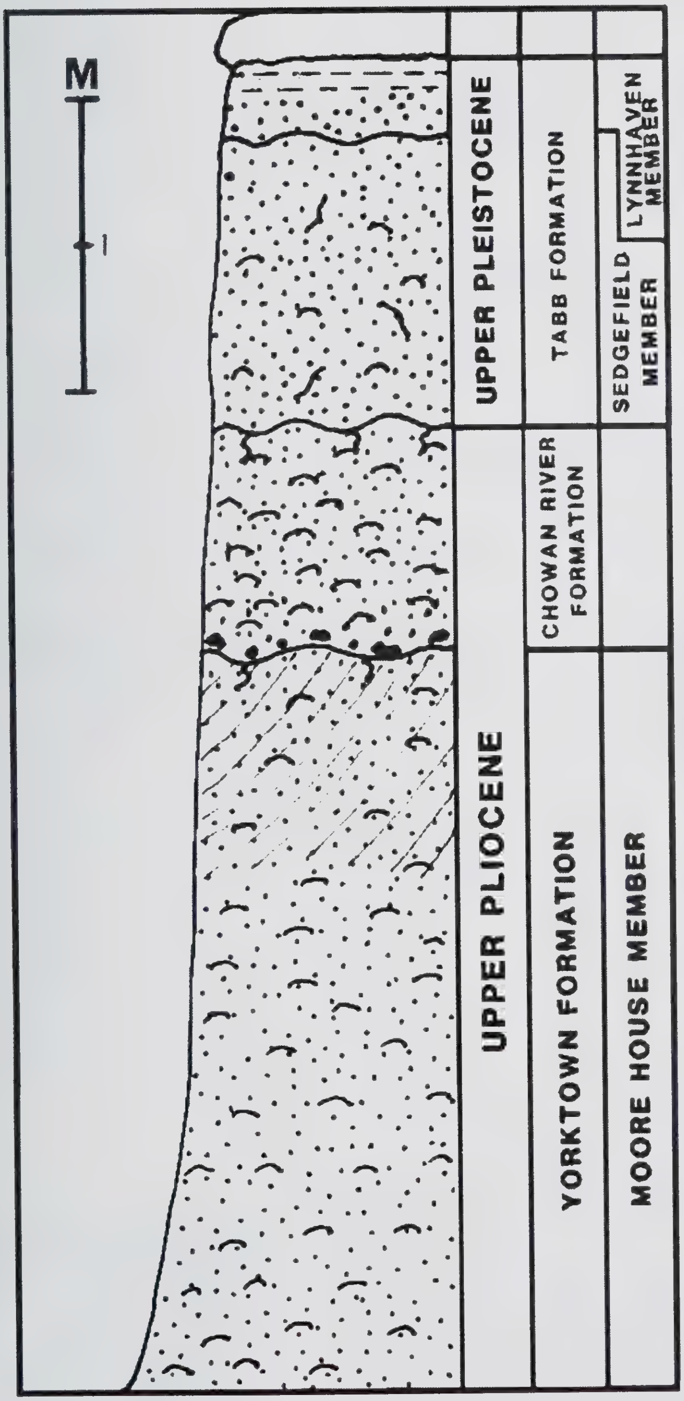


Sand, greenish-gray (5 GY 5/1) where fresh, fine, glaucon, bioclastic, very shelly, diverse assemblage lower contract sharp, burrows into underlying unit, shell becomes finer above, is cross-bedded in places.

Sand, greenish-gray (5 GY 5/1), very fine, silty, shelly; dominated by *Crepidula*

Locality 17

Yadkin Pit, Deep Creek Enterprises, Inc.
3 km northwest of Deep Creek, Chesapeake, Virginia



Sand, grayish-brown (10 YR 6/2), fine, silty, grades to silt above; basal contact sharp, channeled.

Sand, grayish-orange (10 YR 7/4), silty, very shelly, pebbles, cobbles, and rip-up indurated clasts from underlying unit along contact. Many mollusks, moderate diversity.

Sand, greenish-gray (5 GY 5/1), fine, bioclastic, low-angle cross-bedding, dip to the west, many mollusks.

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